TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

JOUNI PAAPPA

ROUGH CUT CAPACITY PLANNING IN MAKE-TO-STOCK PRODUCTION

Master of Science Thesis

Supervisor: Professor Paul H. Andersson
Supervisor and subject accepted at meeting of faculty of Automation, Mechanical and Materials Engineering on 7th of November 2012.

TIIVISTELMÄ

TAMPEREEN TEKNILLINEN YLIOPISTO
Konetekniikan koulutusohjelma
PAAPPA, JOUNI: Varasto-ohjautuvan tuotannon karkeasuunnittelu
Diplomityö, 62 sivua, 10 liitesivua
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Pääaine: Koneteollisuuden tuotantotekniikka
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Avainsanat: tuotannon karkeasuunnittelu, liikkuvat pullonkaulat, työnjärjestely

Tutkimuksen kohteena olivat kappaletavaratehtaan tuotannon ongelmat. Kohdetehtaalla oli vaikeuksia pitää luotua tuotantosuunnitelmaa. Tämä aiheutti haittaa varsinkin tuotantoyksikön toimiessa organisaation muiden funktioiden kanssa. Ongelmaa oli pyritty ratkaisemaan aika – ja materiaalipuskureilla.

Tuotantoyksikön tilanteeseen ja tuotantoympäristöön tutustuttiin. Metodina käytettiin kysyntätietojen analysointia, tuotantoprosessin selvittämistä ja tehtaanlattialla ja tehtaan ulkopuolella näkyvien oireiden tutkimista. Organisaatio oli haasteellisessa muutostilanteessa ja tuotantosuunnitteluosaston toimintaan ei ollut mahdollista tutustua syvällisemmin. Tutkimuksen tavoitteeksi määräytyi perehtymisen jälkeen konseptin kehittäminen tehtaan tuotannon kapasiteetin karkeasuunnitteluun.

Työn tuloksena on identifioitu pääongelma ja esitetty ratkaisuehdotus. Konsepti Excel – pohjaisesta tuotannon karkeasuunnittelutyökalusta on kuvattu. Lisäksi on selitetty yksityiskohtaisesti kuinka työkalu rakennetaan. Työkalu tekee liikkuvat pullonkaulat näkyviksi. Tämä mahdollistaa työnjärjestämisen tehtaanlattialla niin, että voidaan saavuttaa sujuva materiaalivirta, maksimaalinen tuotannonläpäisyvolyymi, parempi työviihtyvyys, asiakastyytyväisyys ja tuottavuus.

ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
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Research problem was challenges in a bulk production factory. The factory had difficulties to plan and execute production plan. This caused challenges especially when the production unit was interacting with other functions in the organization. The production unit had tried to solve the problem by time and material buffers.

Current situation of the factory and production environment was studied. Analyzing demand data, looking at production process and studying symptoms on the factory floor and outside of the production unit was used as a method. Organization was facing a difficult transformation situation and it was not possible to study well the ways of working of the planning department. After familiarization, the objective of the research was formulated as development of concept to the production rough cut capacity planning.

As a result of the research is main problem identified and solution proposed. A concept for an Excel based rough cut capacity planning tool is descripted. Also how to build this tool is explained in detail. Rough cut capacity planning tool makes moving bottlenecks visible. This makes it possible to organize the work on the shop floor well. Smooth material flow, maximum through put volume, better personnel satisfaction, customer satisfaction and profitability can be achieved.

PREFACE

Production planning and control is these days more and more connected to other functions in the company. It is not so much about only optimizing inside the production unit. It is about optimizing the whole supply chain from a tier X supplier to an end customer. That's why often these days when talking about production planning and control, term operation management is used. In production planning and control methods evolve in ever increasing phase as a speed of change in the world continues rising. World is getting more and more connected. Information and capital is everyday flowing faster and more freely than yesterday. Capital moves there were it can be best utilized by using the newest best knowledge in the world. Organizations should be always for a look out for newer more effective ways of working. If organization is not able to learn and change fast enough, it will be run over by competitors. For the writer of this thesis most of the learning when doing this project was not subject learning. Most of the learning happened in how to drive a change in an organization or bring new ideas to it.

When doing this production development project it was a great benefit to be able to communicate with shop floor workers. Personal view is that a lot of the problems arise from shop floor. A problem that looks huge and complex on management level can come from a small thing on the shop floor which is easy to solve. So you solve the root cause and not try to control the problem by for example throwing a huge IT- investment at it or building a complex reporting system. Shop floor workers in target organization didn´t speak English so knowledge of the local language, Swedish, was essential.

The human factors and specially working in multicultural environment made this thesis project very interesting. What made this project environment multicultural was that I had a different cultural background than the rest of the people who this project touched.

I learned that when working in group of humans the subject know how or is the idea good is not the main thing that matters. There are hierarchies, targets, suboptimising, already agreed projects, conflicting visions, customs, ways of working and different organizational cultures. There are also open desires, hidden personal desires, guarding of one´s reputation, anger, fear, jealousy, joy, etc. When working with humans, you have to same time work with the whole range of human emotions. You have to be more aware of the human factors when presenting new ideas than when doing operational work. New ideas are always connected to change. Change is scary; change is a step to something unknown and hits often to one´s insecurities. The weaker the mandate to bring new ideas in is, the more attention to human factors has to be given and more patience and time is needed to be able to build momentum.

Thanks to the team involved. Thanks also for Professor Paul H. Andersson for supervising the thesis and for Assistant Professor and founder of Lean Association Finland Ilkka Kouri for his thoughts.

Special thanks to Sandvik Supply Chain IT Processes Specialist John Salyer for the time and supplying me with the demand raw data and for Production Specialist Bertil Norgren for taking the production raw data out from production system COOL.

The biggest thanks go to Production Unit Manager Jonas Gustavsson for taking the ownership of this project and supporting it. Without Jonas´ support, would have this Master Thesis fallen apart and have not been done.

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ABBREVIATIONS AND NOTATIONS

APS	Advanced Planning and Scheduling
COGS	Cost of Goods Sold
DTH	Down The Hole, a drilling technic and technology
ERP	Enterprise Resource Planning
IDS	Integral Drill Steel, a drilling product
I/O	Input/Output control, in context of short term control in MRP 2
IT	Information Technology
JIT	Just-In-Time, Japanese production ideology
KPI	Key Performance Indicator
MES	Manufacturing Execution System
MOM	Manufacturing Operations Management
MPS	Master Production Schedule
MRP	Material Resource Planning
MTO	Make-To-Order
OI	Order Intake
PU	Production Unit
P&C	Planning and Control, refers mainly to a production unit´s planning and control
RCCP	Rough Cut Capacity Planning
S&OP	Sales and Operations Planning
TOC	Theory of Constraints
WIP	Work-In-Process, refers to stocks in a manufacturing process

1 INTRODUCTION

1.1 The company

Sandvik is a global industrial group with advanced products and world-leading positions in selected areas – tools for metal cutting, equipment and tools for the mining and construction industries, stainless materials, special alloys, metallic and ceramic resistance materials as well as process systems. In 2011 the Group had about 50 000 employees and representation in 130 countries, with annual sales of more than 11 200 MEUR. (Sandvik Group 2012).

New head of Sandvik Group was appointed during 2011. He started organizational change. On 1.1.2012 the new organization model was officially in place. Lot of changes had to be made and company is still adapting to the new organizational model and trying to organize everything to fit to the new model.

Sandvik Group is divided into five business areas. These are Mining, Machining Solutions, Materials Technology, Construction and Venture.

1.1.1. Sandvik Mining and production unit Sandviken

Sandvik Mining is a business area within the Sandvik Group and a leading global supplier of equipment and tools, service and technical solutions for the mining industry. The offering covers rock drilling, rock cutting, rock crushing, loading and hauling and materials handling. In 2011 sales amounted to about 3 800 MEUR, with approximately 13 200 employees (pro forma rounded numbers) (Sandvik Group 2012).

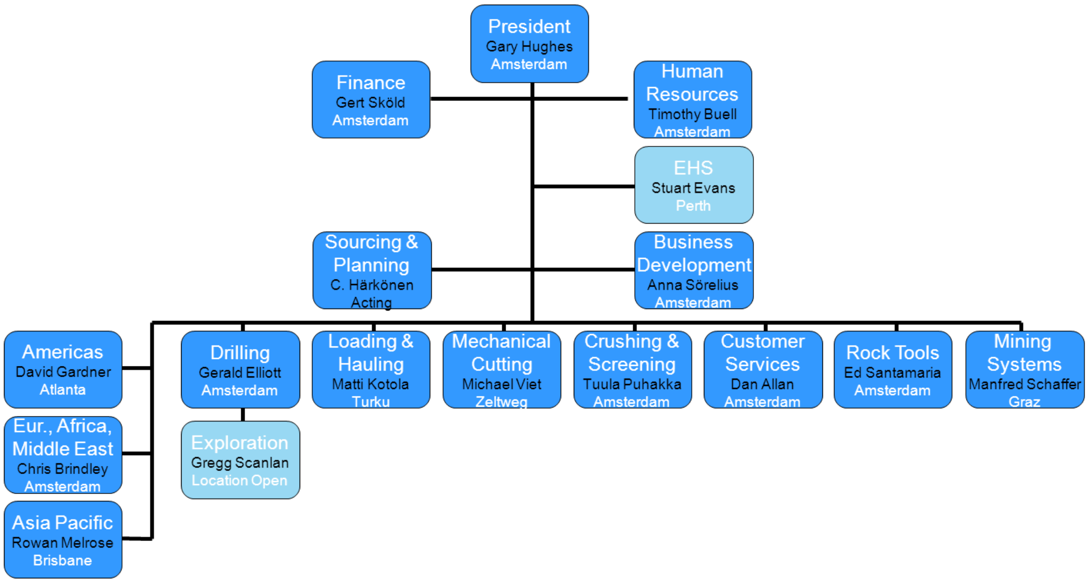

Figure 1.1. *New organization of business area Sandvik Mining (Sandvik Group 2012).*

Target production unit of this study, Sandviken, is a part of Rock Tools product area. Rock Tools belongs to the Mining business area. One purpose for the Sandvik Group reorganization was to make the organization more customer-oriented. New organization of product area Rock Tools is presented below. It is driven by a salesman Ed Santamaria.

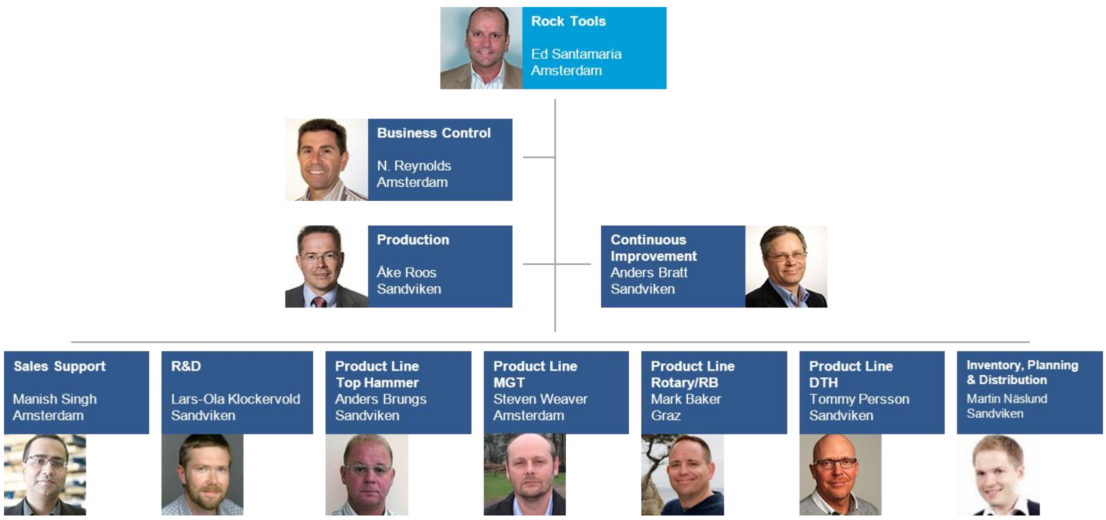

Figure 1.2. *New organization of product area Rock Tools (Sandvik Group 2012).*

Production is under Åke Roos and he is stationed at city of Sandviken. He´s office is next to the PU (Production Unit) Sandviken. Ten factories belong to the product area Rock Tools and Sandviken is the biggest unit.

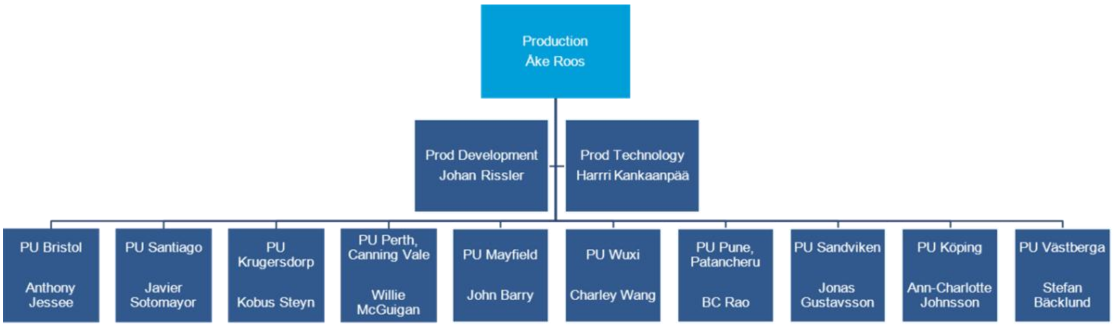

Figure 1.3. *Production units of product area Rock Tools (Sandvik Group 2012).*

Production unit Sandviken is producing top hammer bits, extension equipment, integral drill steels, taper rods and DTH (Down-The-Hole) bits. Floor space is 23000 m^2 and personnel amounts over 400. Manager of the production unit is Jonas Gustavsson.

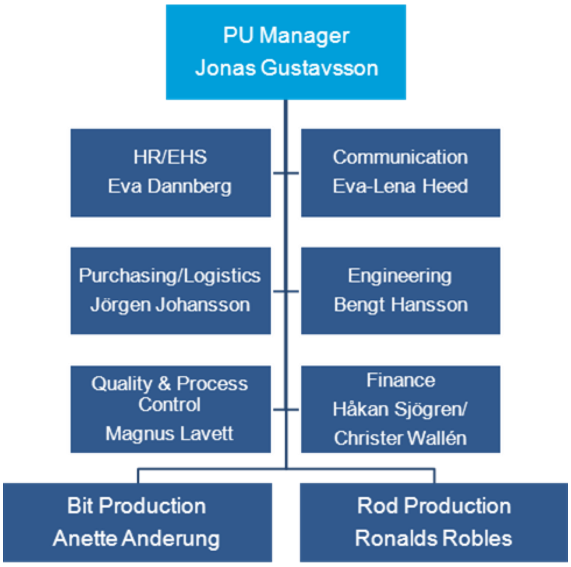

Figure 1.4. *Organization of production unit Sandviken (Sandvik Group 2012).*

Production planning is under Purchasing/Logistics function in the PU´s organization. Scope of the Master Thesis included only rod production. There the production unit faces biggest challenges.

1.2 The research project

1.2.1 The background

Writer worked as a project coordinator in capacity ramp-up project during March 2011 – December 2011. The project was a part of demand and supply balancing project. Product area faced the same situation as many other industries during years 2010 and 2011. After recession caused by global financial crisis on 2008 the economic upturn was fast. During recession production unit Sandviken had also decreased capacity like many others. Raw material prices were high and that made the upturn even more drastic for mining industry than for other industries. Demand came back to its prerecession level and went well above it. The production unit faced the situation that market demand was much higher than capability to supply. When the production unit started to operate more close to its capacity limits, problems started to arise. Old production planning and control methods had worked by having unnecessary excess capacity on the shop floor operations, medium WIP –stocks (Work-In-Process) and loose way to calculate factory internal delivery accuracy and other time buffets. In low demand situation and with these measures factory had previously still been able to operate even though world around the production unit and other product area functions had changed.

Consultancy group PriceWaterhouseCoopers was taken to rescue the situation. It has a part that is specialized in distribution network development. The consultants started a process called demand and supply balancing, because product area´s sales and operation planning (S&OP) practices were inadequate to handle the situation. Markets were given limits how much they can sell. Certain item mix and production capacity was allocated to each market. At the same time capacity ramp-up project was started in production units Sandviken, Krugersdorp and Patancheru. Sandviken was the biggest unit.

During the ramp-up project the writer got familiar with the problems in production unit Sandviken and came to conclusion that most of the problems arose from production planning and control and how work on the shop floor was organized. Master thesis project was started first of January 2012 to look closer modernization of production planning and control. Objective was to make a proposition what changes would be needed to make the production unit match to what was expected from a production unit today in sense of cost efficiency, delivery accuracy, flexibility and control.

Project was originally sponsored and supported by Vice President Production Units Supply Chain Juha Kirjalainen. During 2011 was the CEO of the Sandvik group changed. He started to reorganize the organization. Old supply chain organization was deconstructed and Juha Kirjalainen appointed to a new position. The new group organization was in place first of January 2012. Head of production unit Sandviken Jonas Gustavsson was willing to take the sponsorship of the project. By the change of sponsor the scope of the project also came more PU Sandviken specific. During that time PU Sandviken and the PU planning and purchasing department were under a lot of changes. That made the environment challenging for a master thesis project.

1.2.2 The objective

Project kick off meeting was held at the middle of February 2012 in Sandviken in Sweden. Team decided was PU Sandviken planning and purchasing department manager Jörgen Johansson, Master production planner Erika Ohlsson, Global planning manager Henrik Zettergren and Professor Paul H. Andersson from Tampere University of Technology.

Topic was from monthly to daily planning in production of mining tools; proposing a new process for creating daily production plan for bottlenecks to maximize output and minimize WIP. Limitations were that the thesis looks only at rods production inside PU Sandviken. Suppliers and processes of the product area´s Global Planning function were not included in the scope.

Situation of the factory and production environment was studied and determined what would be a feasible project. At that time the organization was facing a difficult transformation situation.

At the end of March 2012 the objective was set.

- Create a concept for rough cut capacity planning tool which simulates the effect of product mix on moving bottlenecks on one month to three years' time intervals

The production unit had few main targets for the coming years.

1. Personnel safety
2. We keep what we promise – Improvement in making and executing production plan
3. Cost reduction - Improvement in productivity and other cost savings

The objective supported second and third targets. How it helps the PU achieve its targets is dealt in more detail in chapter 6. Result.

1.2.3 Methodology

The study was conducted by utilizing writer´s earlier experience working with the production unit and studying production environment deeper. Few times during six months writer flew to Sandviken in Sweden to spend a week at the site. These trips were mainly for information collection purposes. Most of the work was done at the Tampere University of Technology and at the writer´s home in Finland.

Studying at the symptoms inside and outside of the production unit and input values (i.e. nature of demand) was used as a main method in the research.

Information was collected by interviewing personnel in different hierarchy levels. Most of the time was spend with personnel close to production including blue collar shop floor workers. Ways of working in the production planning department was not been able to be studied deeply. Organization was going through a difficult change and personnel in the department were taking in new roles. Also data in numbers about demand and production was gathered and analyzed.

2 THEORY

Success of an industrial company on the market depends on its capability to produce fast and cost efficiently products which satisfy customer needs. This requires comprehensive control of order-delivery process and effective use of production resources. All the company activities are part of operations management as well as planning and control of production process. Good decision making process in production planning and control requires reliable and up-to-date information from for example marketing, sales, production, material administration and personnel department. Utilizing this knowledge from different activities is possible with the help of unified IT-systems and system modules attached to them (Vuorenpää 2007).

2.1 Operations management

Slack & Lewis (2002, p. 5) define operations management as activity which helps to control those resources and processes which produce and deliver goods and services. They are comprehensively addressing operations management of all the company´s value adding activities. Term production planning and control is often replaced by operations management term because comprehensive operations management requires also planning and control of sales, product development, purchasing and distribution and not only production (Haverila et al. 2005, p. 397).

With the help of operations management and with the decision making involved, company´s activities are been planned and controlled. Three different functions of an industrial company can be separated and categorized as seen on the figure 2.1. Financing function makes sure the different activities are financed in a good way so that the company can operate. Marketing function is responsible for evaluating customer needs and product marketing, advertising and sales. Production function is responsible for producing goods and services (Stevenson, 2007, p.4).

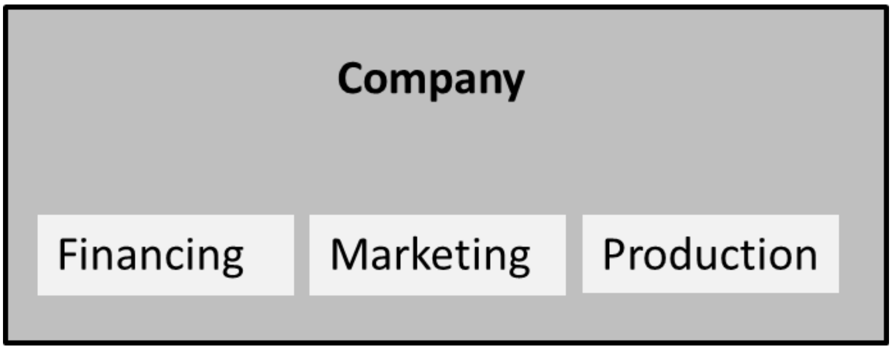

Figure 2.1. *Main functions of an industrial company (Stevenson, 2007, p. 4.adapted)*

In this Master Thesis is mainly production studied and term planning and control used to refer to production Planning and Control (P&C).

2.1.1 State of production P&C in bulk production companies

Often the production P&C methods are insufficient in companies which run bulk production. Investments and development projects are normally targeted only to production technology meaning that developing production P&C methods is left behind (Hemilä et al. 2009, p. 7.). Old and inefficient P&C methods and tools are not helping comprehensive control of the production process. This causes that production flow streamlining can be poor and lead times and customer delivery times long. Bad control over production process makes it difficult for a company to upkeep delivery accuracy and it deteriorates customer satisfaction. Target company of this study, production unit Sandviken, is facing this typical situation.

Companies often have or purchase an operations management system which mainly supports the needs of material administration and finance department. They are not designed to make P&C of production process more efficient. In bulk production industry the focus is on effective use of production resources like personnel and machines. To be able to do this, it requires production/capacity plan for resources. Based on the plan is detailed work scheduling for the production resources formed. When making the capacity plan, it is useful to use visual tools which make the planning more clear (Hemilä et al. 2009).

2.2 Planning and control methods

Production planning and control systems are not separate functions inside companies. They are very tightly linked to a company´s ideology and ways of working. Sometimes planning and control systems can be dependent on a local culture. For example Just-In-Time (JIT) works well in Japan but not so well in the USA (Kantola 1996, p. 21-22).

For example the roots of JIT undoubtedly extend deep into Japanese cultural, geographic and economic history. Because of their history of living with space and resource limitations the Japanese are inclined toward conservation. This has made tight material control policies easier to accept in Japan than in the throw-away society of USA. Eastern culture is also more systems-oriented than the Western with its reductionist scientific roots. Policies that cut across individual workstations, such as cross-trained floating workers and total quality management, are more natural in this environment. Geography has also certainly influenced Japanese practices. Policies involving delivery of materials from supplier several times per day are simply easier in Japan, where industry is spatially concentrated, than in USA with its wide-open spaces (Hopp & Spearmann, 2000). Analogy can be drawn with the management of an organization. When an organization is given too much living space (i.e. not enough pressure) and gets resources (i.e. investments) fairly easy, organization tends to start to incline away from conservation and wastes start to build up.

Another example how culture and surrounding society is affecting ways of working. A machine is build and tested in China. Then it is deconstructed and shipped to Scandinavia. All the bolts and nuts are put in to one basket. When the shipment arrives, a mechanic starts to build up the machine. He swears how the Chinese can be so stupid that they put all the bolts and nuts together. When the mechanic needs the specific 20 bolts, it takes one hour to find the 20 bolts from a basket containing 1000 bolts. In this case the main point what both parties missed here was the labor cost difference. Purchase price for 20 bolts can be 1 euro but one hour Scandinavian work cost maybe 40€ for a company. So, now the price of the 20 bolts is 41 €. In China you can have an uneducated farmer, who started to work in factory, looking for needed parts and he will cost maybe 0.4€ per hour. So, it´s not a big deal in China (Chen 2012).

In India, if you hire a person it is almost like a lifetime commitment. People are difficult to fire. Emphasis in the society is more on the idea that companies offer people work than making money. Wellbeing comes from a lot of people working and not by the wealth companies generate for themself and individuals. Important is that people have work even though it would not be productive. Uneducated labor is often also really cheap so it should not be a big deal for company if they keep a person or not. This way of the society pushing a little bit companies to keep their personnel is also substituting for poor social benefits safety net of the society. Hiring and firing, as one capacity flexibility tool, is more restricted than in many other countries (Rao, B.C. 2011). India is also missing the rental workforce companies system which for example Sweden has. In case of Sweden it brings flexibility to a company´s operations by increasing labor market dynamics in the society which otherwise has fairly strict labor laws.

2.2.1 Material Resource Planning 1 and 2

MRP 1 (Material Resource Planning) was developed in 1960th in USA. In MRP 1 material requirements are calculated with the help of product structure. Calculated material requirements are been examined against current stocks and material orders to suppliers which have not yet arrived to the factory. Basic assumption and requirement for MRP 1 is that demand of the final products can be forecasted. The purpose of MRP 1 was to replace routine work. To actual production capacity planning MRP 1 didn´t bring any help and it had to be done separately (Slack et al 2001).

In 1970th material requirements calculation and capacity planning were united. The method received name MRP 2. Production capacity was noted when doing material requirement calculations. In production capacity planning, the different capacity requirements for different customer orders were calculated based on operation times in different manufacturing operations on the shop floor. Planning different item mix and scheduling combinations was fast (Miettinen 1993, p.50).

2.2.2 Just In Time

At the beginning of 1980th was started to look for new P&C methods because MRP 1 and MRP 2 were no longer able to work well in changed environment. Reasons for that were mostly following (Miettinen 1993, p.51):

1. Competition on customers became harder
    a. Customers had to be offered more different type of production variations which meant batch sizes in production became smaller
    b. Lifespan of products became shorter
    c. Delivery time and delivery requirements became stricter

2. Prize of capital became higher
    a. Capital which was tight up in work in process stocks and other stocks was been tried to minimize.

Japanese developed JIT –principal (Just-In-Time) to P&C of repetitive production. The principal says that simplicity is the key for effective P&C. In ideal case in JIT –world: “Only necessary products as only as large batches as necessary when they are needed” (Miettinen 1993, s.51). JIT has proven to be better as traditional operating model in many areas. JIT was born in production where standard products were produced but it´s principles and operating models can be also applied successfully in other production environments (Slack et al.2001, p. 481-509).

JIT operating model is based on clearly structured production. Materiel flows and P&C are organized as effectively and clearly as possible. Repetitiveness of different products and shop floor operations is high. Factory layout is compact and material flows are simple and clear. Production system allows high variability in demand inside a product group but variability in total volume for each of the product groups has to be low (Heizer & Render 2006, p. 628-645).

Lot of the development work in JIT production is based on shortening the set up times. Short set up times make small batch sizes possible without any loses in profitability. Small batch size automatically shortens production lead times. Production layout is developed to follow a product´s work order which makes it possible to decrease the WIP –

stocks even further. This way the lead time of a product decreases drastically. Production can respond better to demand changes inside a product group and products can be better manufactured based on actual customer order. The production can be run based on Make-To-Order (MTO) principle. Everything is done Just In Time and not to stock. As a P&C method on the shop floor can be kanban pull method used (Slack et all, p. 481-509).

JIT production requires high quality in ways of working. Cost of quality deviations is high because they stop quickly the whole production. On the other hand, because of clearness and fastness of JIT production also the deviations and reasons for them are easily to be found. Development work is easier to carry out (Miettinen 1993, p. 52-57).

2.2.3 Lean management

Lean management was born in Japanese car industry. It is a way to organize and run operations in a way in which lightness and flexibility are typical – the products and services which customer wants are tried to be produced with as little resources as possible. The aim is to simplify production activities so that all the work that doesn´t add value can be cut away. Value of operations is measured based on the added value it brings to a customer. For example the quality department can be closed down if stabile and required quality can be produced without the aid of it. Lean has plenty of common features with JIT.

In following are some of the principles of light and flexible operations mentioned (MET 1992):

- customer focus in all activities
- quality in all activities
- decentralizing responsibility, everyone is responsible for his/hers work
- all resources are sized exactly based on needs
- low and multi-skilled organization, which is been educated heavily
- cooperation and group work
- constant comparison with competitors and best-in-class (so called Benchmarking)
- continuous improvement principle (Kaizen)
- flexible production system and pull based P&C
- streamlined production and material flows
- short lead times
- short lead times in production and as a whole
- minimizing work in process and final product stocks.

Company´s operations are constantly compared with operations of competitors. Operation models and practices of best-in-class companies are analyzed. They are used when developing own activities. The purpose is not to mimic other companies. It is to find ideas and learn from the others. This type of activity is called benchmarking (Heizer & Render 2006, p. 641-645; Halevi 2001).

2.2.4 Theory of Constraints

Eli Goldratt (1947-2011) developed at 1980´s production planning and control (P&C) and development method called Theory Of Constraints (TOC). The central hypothesis was that every system has at least one factor limiting it from reaching its goals. That factor can be called a bottleneck. TOC was originally built for production but later Goldratt extended it to cover for example logistics, sales, marketing and project management. Key finding and point in the theory is that it is useless to produce something that won´t go smoothly through the bottleneck and is piled on the shop floor. Capacity of the bottleneck is the capacity of the whole company and it dictates the volume of the through put flow and this way determines the profit making capability of the company (FPCA 2012). One hour lost in the bottleneck is equal to one hour lost in whole production of a factory.

In TOC the KPIs (Key Performance Indicator) for evaluation the success of a company are net profit, Return On Investment (ROI) and cash flow. All of these three are tried to be improved simultaneously. There is only one goal in TOC: company´s goal to make money now and in future (Kantola 1996, p. 24; Haveli 2001).

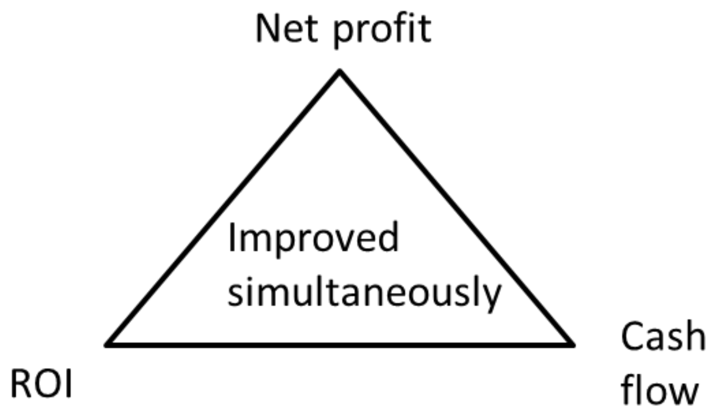

Figure 2.2 *Goal of TOC is to improve net profit, ROI and cash flow simultaneously (Kantola 1996, p.24).*

2.2.4.1 Theory of Constraints as planning and control method

Starting point for TOC has been JIT. TOC tries to combine the best sides of MRP 2 and JIT - Effective databases and good utilization of Information Technology (IT) from MRP 2; clear and simple material flows and work organization, development methods and minimizing wastes from JIT (Miettinen 1993, p. 58).

TOC has following ten principles (Slack et al. 2001):

1. Balance material flow, not capacity.
2. Utilization rates of non-bottleneck resources determine the needs of the critical resources.
3. Activating and using a resource is not the same thing.
4. One hour lost in bottleneck resource equals one hour lost in whole production of a factory.
5. One hour won in non-bottleneck resource is illusion. It is useless.
6. Bottleneck resources determine through put volume and size of the stocks.
7. Transport batch is not necessary the same, and often also has to be different, as manufacturing batch.
8. Manufacturing batch size should be flexible and not standard.
9. Realized lead time is determined based on scheduling, and cannot be determined beforehand.
10. When doing scheduling, all the system constraints should be taken into consideration simultaneously.

2.3 How should development projects be prioritized

Everything should not be developed all the time. Developing is expensive and people have limited capabilities to adapt to changes. That´s why development activities should be focused on the issues that have a crucial effect on a company´s profit making capability (FPCA 2012). A company´s main purpose after all in most cases is to make money for its shareholders. For example 624/2006 Finnish Limited Liability Companies Act (Finland Ministry of Justice 2012) states in section five: “The purpose of a company is to generate profits for its shareholders, unless otherwise provided in the Articles of Association.”

TOC can help to find the focus but is not the answer to all the problems. Not a single P&C or development method is that good that a company could only use that. It is a sad fact that at least in Finland there is a room only for one concept at one time. The one has long time been Lean, which is good, but it has to be used correctly. At the moment in world there is spreading a combination of three different methods. It is called TLS meaning TOC, Lean and Six Sigma. On 2006 was a study published which started this. Study showed clearly that with the combination of these three methods supreme results were achieved compared to results by using only Lean or Six Sigma. (FPCA 2012). First the focus of development is determined with TOC. Then LEAN is used to decrease waste on key points and Six Sigma to decrease variation (Sproull 2009).

2.4 Enterprise Resource Planning

Markets set requirements for a company´s operations´ flexibility, quality, costs and fastness. Bringing new products to the market and controlling the order-delivery process requires cooperation of different departments. Comprehensive control of the order-delivery process requires effective use of personnel, production resources, spaces, stocks and company´s internal information (Shtub 1999). Company´s information processing and operations planning and control needs are integrated as one entity called Enterprise Resource Planning (ERP) (Haverila et al. 2005, p. 430). ERP unifies the tools used by different departments by putting them to the same database. These departments are for example purchasing, sales, production, production planning, logistics and human resources. According to Stevenson (2007, p. 656) information flows freely inside a department but often information doesn’t flow well between different departments. With the help of ERP system the information is been put in to the system once and is then available for all the departments (Haverila et. al. 2005, p. 430).

2.4.1 Material Resource Planning 2 in Enterprise Resource Planning

There are many different hierarchies and ways functions are organized in MRP2. It differs somewhat depending on a software vendor and a company. Most of MRP2 system vendors call themselves ERP software vendors these days (Hopp & Spearmann 2000. p. 136).

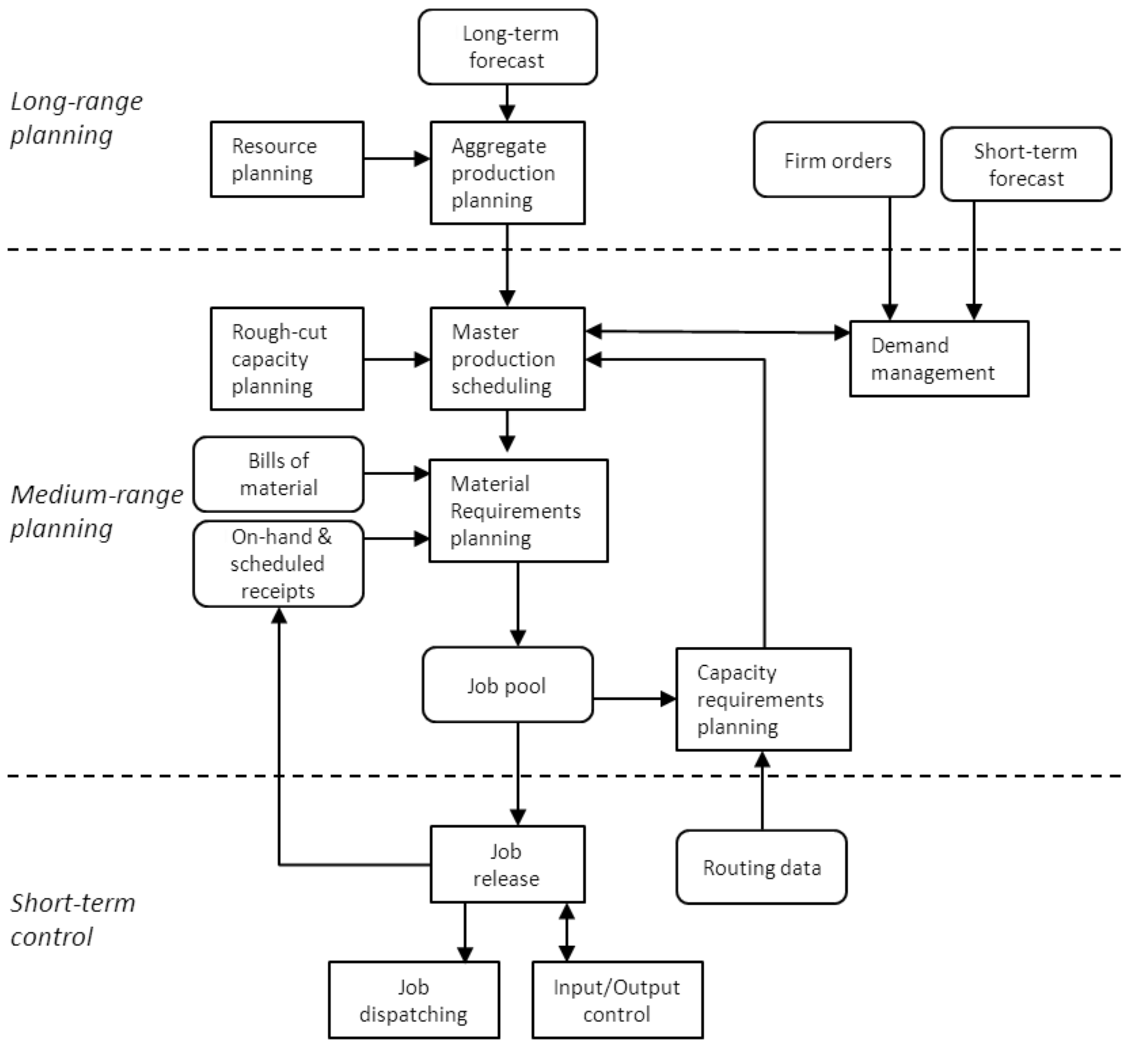

Figure 2.3. *One example of an MRP2 / ERP system hierarchy (Hopp & Spearman 2000, p.136).*

At the top of hierarchy we have long-range planning (Fig.2.3). The length of the time horizon for long-range planning ranges from around six months to five years. The frequency of planning is typically two to four times per year. The degree of detail is typically at the part family / product group level (i.e., a grouping of end items having similar demand and production characteristics).

Forecasting function predicts the demand in the future and is input to the medium-level function of demand management. An important output of resource planning is projected available capacity over the long-term planning horizon. For resource planning and aggregated planning is the example tool developed in this master thesis project helpful. Aggregate planning is used to determinate levels of production, staffing, inventory, overtime, and so on over the long term. The level of detail is typically by month and for product families. For instance, the aggregate planning function will determinate whether we build up inventories in anticipation of increased demand (from the forecasting function), chase the demand by varying capacity using overtime, or do some combination of both. Optimization techniques such as linear programming are often used to assist the aggregate planning process.

At the middle section is medium-range planning. At this level, there is a bulk of production planning functions. One of the functions is Rough-Cut Capacity Planning (RCCP). It is used to provide quick capacity check of the few critical resources to ensure the feasibility of the Master Production Schedule (MPS). RCCP makes use of a bill of resources for each end item on the MPS. The bill of resources gives the number of minutes required at each critical resource to build a particular end item. These times include not only the end item itself but all the exploded requirements as well.

An example tool built in this Master Thesis project is functioning as a RCCP – tool but doesn´t respond exactly to the description above. The example RCCP –tool is adapted to fit the factory´s situation and production environment.

Capacity Requirements Planning (CRP) provides more detailed capacity check. Necessary inputs include all planned order releases, existing WIP positions, routing data, as well as capacity and lead times for all process centers. In spite of its name, CRP does not generate finite capacity analysis. Instead, CRP performs what is called infinite forward loading. CRP predicts job completion times for each process center, using given fixed lead times and then computes a predicted loading over time. The loadings are then compared against available capacity.

At the bottom of the hierarchy is short term control. The plans generated in the long- and medium-term planning functions are implemented in the short-term control modules, of job release, job dispatching, and input/output control.

Job release converts planned orders to scheduled receipts. One of the important functions of job release is allocation. When there are several high-level items that use the same lower-level part, a conflict can arise when there is an insufficient quantity on hand. By allocating parts to one job or another by wanted allocation-logic, the job release function can rationalize and solve these conflicts. A material shortage note would be generated for the other job which was not started and that job would remain in the job pool until it could be released.

The basic idea behind job dispatching is simple: Develop a rule for arranging the queue in front of each workstation that will maintain due date integrity while keeping machine utilization high and manufacturing times low. Many rules have been proposed for doing this.

Input/Output (I/O) control was first suggested by Wight (1970) as a way to keep lead times under control. I/O control works in the following way:

- Monitor the WIP level in each process center
- If the WIP goes above a certain level, then the current job release rate is too high, so reduce it.
- If it goes below a specified lower level, then the current job release rate is too low, so increase it.
- If it stays between these control levels, the job release rate is correct for the current conditions.

The actions – reduce and increase – must be done by changing the MPS.

I/O control provides an easy way to check releases against available capacity. However by waiting until WIP level have become excessive, the system has, in many respects, already gone out of control. This may be one reason that so-called pull systems (e.g., Toyota´s Kanban system) may sometimes work better than push systems such as MRP, MRP2 and ERP. While these systems control releases (via the MPS) and measure WIP levels (via I/O control), Kanban system control WIP directly and measure output rates daily. Thus, Kanban does not allow WIP levels to become excessive and detects problems (i.e., production shortfalls) quickly.

2.4.2 Lack of support for production processes

ERP systems often have insufficient tools for optimizing production processes. This is reason why companies often get separate solutions and systems which help to improve efficiency. Separate tool for production planning and control is useful no matter is the company getting later a companywide ERP system or not (Bendoly 2005, p. 56).

One alternative to supplement the functionality of an ERP system is Advanced Planning and Scheduling –system (APS). APS extends the functionality of ERP system by modules which make possible to control demand and resources plus to optimize and allocate production resources. With the help of APS it is possible to form a production system a schedule. The schedule takes into consideration demand, production capacity and available materials (Fig. 2.9) (Lai & Cheng 2009).

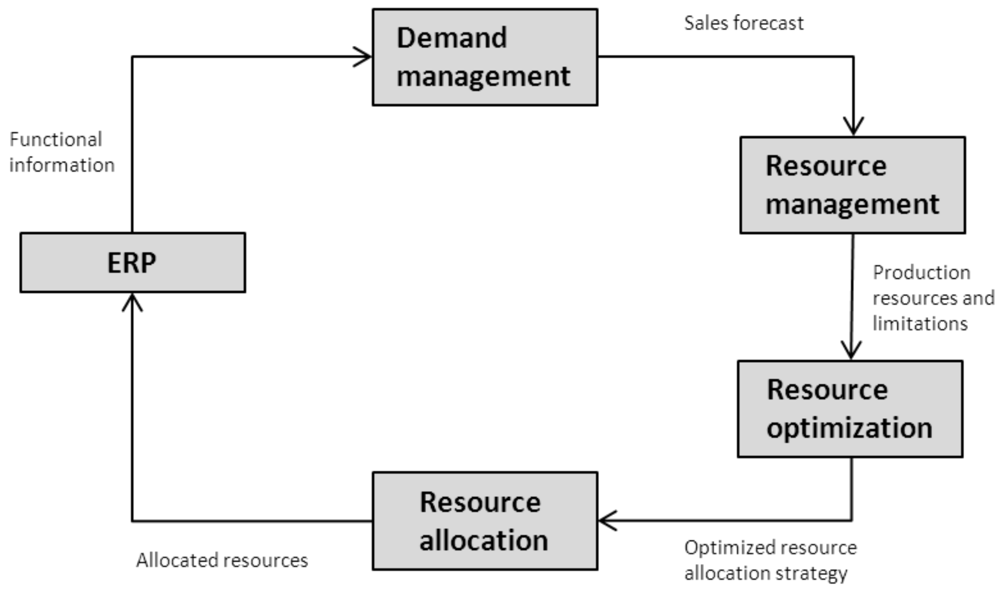

Figure 2.4. *Functionality of an APS system (Lai & Cheng 2009, p. 95).*

Another alternative to supplement the functionality of an ERP system is Manufacturing Execution System (MES). APS and MES are both Manufacturing Operations Management (MOM) systems. APS is bit more planning centered whereas MES is executing centered. MOM/MES system has usually two modules. Planning module which handles scheduling and resource management and control module which handles shop floor work orders and collection of production information.

The most important purchasing arguments for MOM/MES system are improvement in productivity and in the size of business. Benefits are easily measurable like shorter lead time, lower WIP and improved delivery accuracy without regular time and material buffers. It gives also a better possibility to control the supply chain and changes in production plus planning is faster and includes less mistakes. Also, visibility over factory walls, possibility to simulate different planning alternatives and monitor production globally, continue the list of benefits (FPCA 2012).

International ICT consultants propose portfolio model (best-of-breed) as IT –system of an industrial forerunner companies instead of one (ERP) model. From production point of view should an IT –system have at least ERP and MOM/MES –system integrated to it according to study done by Aberdeen Group in best-in-class companies (Littlefield & Shah 2010). Same IT –system combination is supported also by Gartner (Lausala et al. 2010) and (Mansson 2007).

2.5 Sales and Operations Planning

One way to organize and look at long-range and medium-range planning can be following, so called Sales and Operations Planning (S&OP). On general level it does not dependent on is MRP, Kanban or some other P&C method used. The general purpose of functions is similar no matter what the production and business environment is.

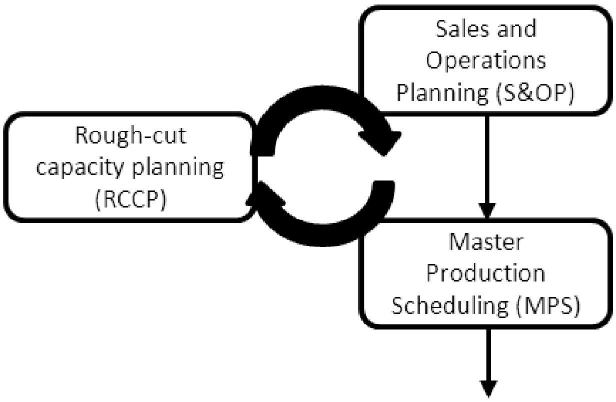

Figure 2.5. *S&OP process (Kouri, I. & Kaataja,M. 2010).*

With the help of S&OP is preliminary production plan formed. Reliable information from sales forecasting and from available capacity is required. Goal is to find balance between demand and production capacity in a way that best customer satisfaction – cost ratio can be achieved (Fig.2.5). The balance is formed by changing capacity, demand or both. Plan is often one month or quarterly rolling.

The most important information when doing S&OP usually is following (Stevenson 2007):

- available production resources
- sales forecast
- procedures for changing personnel resources
- use of subcontracting
- use of overtime
- stock levels and their changes
- after deliveries
- costs:
  - stocking
  - after deliveries
  - hiring and firing employees
  - overtime
  - changes in stock levels
  - subcontracting.

2.6 Difference between Kanban and push method

In push system, such as MRP, work releases are scheduled. In a pull system releases are authorized. The difference is that a schedule is prepared in advance, while an authorization depends on the status of the plant. Because of this, a push system directly accommodates customer due dates, but has to be forced to respond to changes in the plant (e.g., MRP must be regenerated). Similarly, a pull system directly responds to plant changes, but must be forced to accommodate customer due dates (e.g., by matching a production level and rate in production plan against demand and using overtime to ensure that the production rate is maintained).

In the MRP system releases into the production line are triggered by the schedule. As soon as work on a part is complete at a workstation, it is pushed to the next workstation. As long as machine operators have parts, they continue working under this system.

In the Kanban system, production is triggered by a demand. When a part is removed from the final inventory point (which may be finished goods inventory) the last workstation in the line is given authorization to replace the part. This workstation then sends an authorization signal to the upstream workstation to replace the part it just used. And so on, each station does the same. In the Kanban system, an operator requires both the parts and an authorization signal (Kanban) to work.

Most real-world systems are hybrids or mixtures of push and pull. There are many different ways to achieve the benefits of pull and it depends on production environment (Hopp & Spearmann 2000).

2.7 Suitability of planning and control method

One way to look at a suitability of a P&C method is to look at complexity of product structures and complexity of the material flows.

Products which have a simple product structure and well standardized manufacturing operations are good for pull based P&C method. This pull based method can be for example Kanban. When product structures and material flows become more complex, the use of pull based methods decreases. In case of very complex product structure a networking tool like PERT (Program Evaluation and Review Technique) is needed (Fig. 2.6).

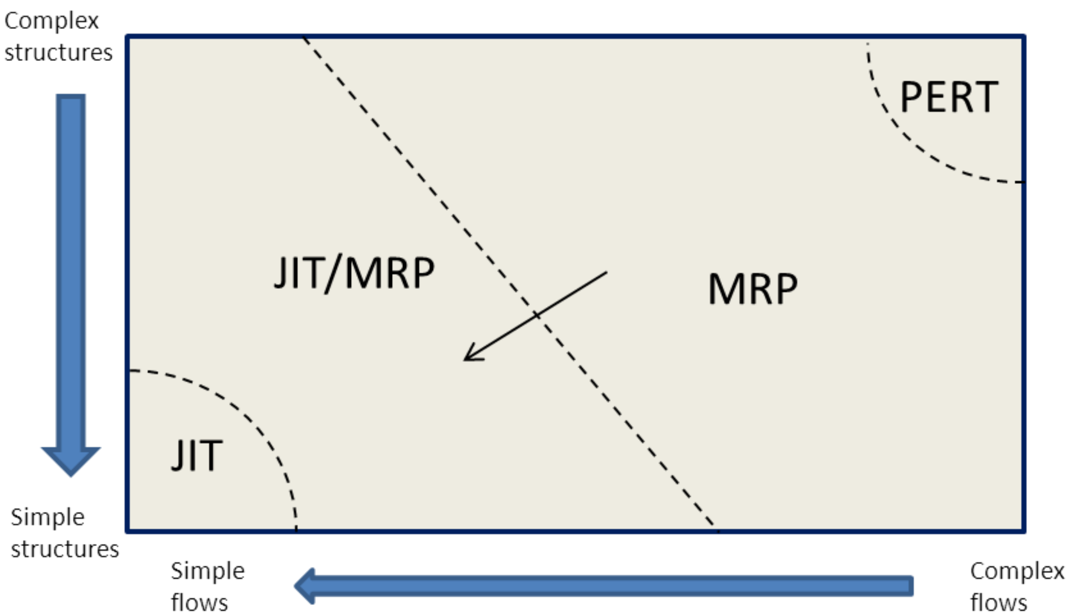

Figure 2.6. *Complexity as a deciding factor (Slack et al. 2001, p. 507, adapted).*

2.8 Simulation

In production planning a simulation type of solution can be used when creating production plan to find out the best production plan, which scheduling for the production plan is most productive and how work on the shop floor should be organized to get the best efficiency in different situations.

In general, ability to simulate how different possible changes affect production system is a good tool for management when making decisions about future plans.

Personnel responsible of production have often clear view of the problems and how these (possibly) could be solved. These development ideas often aren´t applied to practice because of the risks involved. When trying an idea in the simulation, can be function of the system as whole understood better and the effect the idea has on the whole system. Possibilities are easier to evaluate before making the decision. Simulation on the computer is significantly easier and involves fewer risks than trying something in practice. For example unnecessary moving and purchasing of production equipment, personnel recruitment and building new spaces can be avoided. Also ongoing production isn´t disturbed when trying out happens on computer instead of real system.

The biggest benefits of simulation according to Robinson (1994) are:

- risks are lowered
- better understanding of the problem
- decreasing of operating costs
- decreasing of lead time

- faster changes in operations
- lower capital costs
- better customer service.

In simulation can be circumstances repeated again and again. The effect of different kinds of inputs and changes in parameters like work time on a machine can be tested.

2.8.1 Management view

It is possible that the problem could be tested without simulation. Never the less management often favors making the simulation. Possibility to see the simulation as a graphic show and possibility to affect it are it´s great advantages (Robinson 1994, s. 8-9; Law & Kelton 1991, s. 3-7).

- **Simulation encourages creative thinking**

Often great ideas which have a lot of potential are never to be tested in fear of failure. With simulation the ideas can be tested with low cost and encourage personnel to do development work.

- **Simulation aims for comprehensive solution**

Often problems are seen as single problems and end result is suboptimization. Typically some problem is been only transferred to other place and that´s why though to be solved. In reality it is not solved. In simulation it is seen how change in one part of the system affects the system as a whole.

- **Simulation makes people think**

When simulation model is been built and when it been modified during the time when changes in the system happens, people are forced to think operations in more detailed level. Also similar way of looking at the system forms and learning happens.

- **Simulation helps implementation of good new ideas**

Many ideas are been buried because benefits they bring aren’t been able to be presented to busy top management. Visuality of simulation is a great tool for discussion. It makes the effect of the proposed change easier to understand in a system consisting of number of cause-and-effect relationships. It can be that the benefit of the idea is already proved but simulation has to be done to prove it to top management and co-workers.

3 PRODUCTS

Why this section is included? It is included because customer processes determine the product structure and product structure determine the manufacturing operations on the shop floor. This section is included to increase the understanding of shop floor operations. Why the operations are done. It gives a better understand what are the limitations and possibilities when organizing work on the shop floor.

Most of information in the section is from interview on 20.3.2012 with Robert Olsson the Product Manager for Top Hammer Tools – Underground Applications and from Top Hammer Drilling Tools Product Catalog 2008.

For the product groups is in this section wording minor group used.

3.1 Small hole drilling

3.1.1 Minor group T05

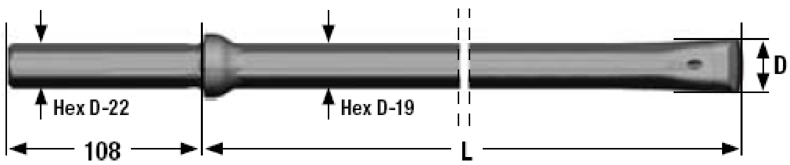

Figure 3.1. *Integral Drill Steel (IDS) (Larsson, K. 2012).*

The product (Fig. 3.1) follows material flow T05 on the shop floor.

This product is used to drill small holes. The holes have the size less than 45mm. It is a basic product. The product has stayed the same since 1940´s. The name Integral Drill Steel (IDS) comes from a product´s structure. All three parts shank, rod and bit are integrated together.
Shanks are 108mm long in these products and also in all the other minor groups. 108mm is an industry standard for shank. It makes shanks compatible with all drilling hammers.

The majority of the integral drill steels are used with hand held rock drilling hammers. Dimensional stone industry is the main user (Fig.3.2). The dimensional stone industry produces tombstones, benches in the kitchen, flooring, etc. The method the industry uses gives high quality rock products meaning that for example in rock there are no

cracks. This type of customer industry is under construction business area in Sandvik. Small part of the sales comes from civil engineering. This as well belongs to the construction business area.
Roughly the rest 10 percent of the integral drill steels market is under mining business area.

Integral drill steels market as a whole has been shrinking last 40 years. Biggest market areas geographically today are Saudi-Arabia and India.

Figure 3.2. *Application. Dimensional stone industry (Olsson, R. 2012)*

3.1.2 Minor group T27

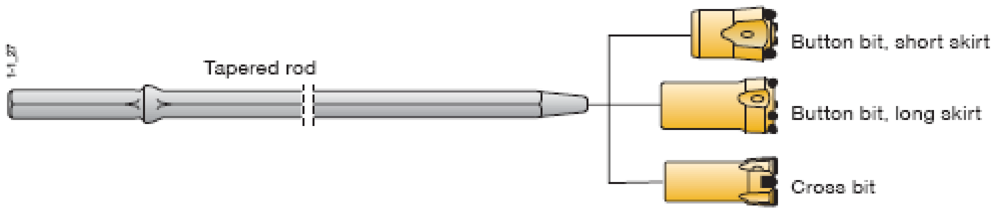

Figure 3.3. *Tapered rod (Top Hammer Drilling Tools – Product Catalog).*

The product (Fig. 3.3) follows material flow T27 on the shop floor and is carburized. Use for the product is mainly hand held underground mining

Tapered rods are similar to integral drill steels but have a bit at the end. The bit gives a longer lifespan for the product. User does not have to through away the rod and shank parts when the end part, which is in contact with rock, is used. Drilling speed is also much faster. It is around 30 percent faster.

Tool management is much easier. Just the bit at the end can be changed on the drilling spot. Rods doesn´t have to be always taken to the grinding/servicing spot like with the IDSs. Out of these reasons the biggest market for the product is hand held drilling in underground mining. It is gigantic in China and also in South-Africa.

3.1.3 Minor group T08

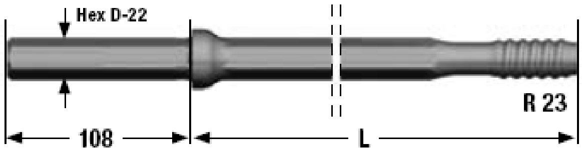

Figure 3.4. *Carburized shank rod (Larsson, K. 2012).*

The product (Fig. 3.4) follows material flow T23, T08, T07, T04 on the shop floor and it's carburized.

Products are used in specialty works in civil engineering and construction. These products are usually the ones a common man sees because they are used close to human habitation. Applications are road constructions, cautious demolition works in city environment, secondary breaking, foundation drilling, trenching and extreme conditions (Fig. 3.5). Market for these products is very small compared to the whole drilling tools market. Production volume in the production unit Sandviken is very low.

Figure 3.5. *Applications for shank rods (Olsson, R. 2012).*

3.2 Drifting and tunneling

3.2.1 Minor group T23

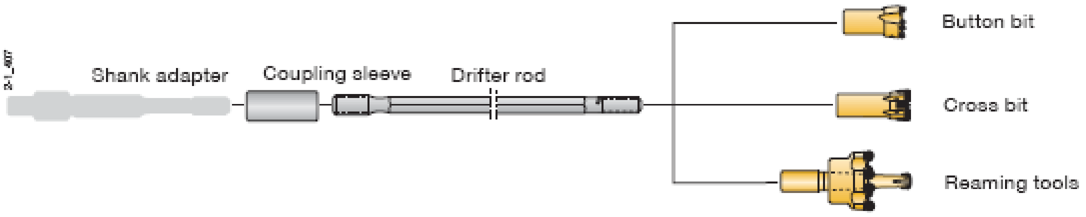

Figure 3.6. *Carburized drifter rod and other parts (Top Hammer Drilling Tools Product Catalog).*

The product (Fig. 3.6) follows material flow T23, T08, T07, T04 on the shop floor and is carburized.

Parts which are primary used when using a drifter rod are a coupling, a drifter rod and a bit. In principal all the underground tools are carburized to prevent corrosion. There is a huge difference in service life as corrosion develops much quicker without carburization

Drifting and tunneling is the biggest market for the rod products produced in production unit Sandviken. Minor group T23 has the biggest production volume in pieces and second biggest volume after MF rods when looking volume in COGS. For production planning and control and shop floor work organization is the product the main interest.

The thread end in a drifter rod is larger than the bit-thread because it is subject to a lot of beating. Product will last longer when the thread end is larger. The tread end can be larger in this case because it never goes inside the hole. No extension drilling is applied in drifting and tunneling.

Drifting is a mining process which is performed in a mine (Fig. 3.7 and 3.8). It is customer process in underground mining and is under business area Mining. 50 - 60 holes which are usually four meters deep are drilled. Then explosives are set and blasting is done. Both in drifting and tunneling, a tunnel like shape is formed into the rock. What on general level differentiates drifting from tunneling is that drifting is done at mines and tunneling is a construction application. In tunneling, typically a larger cross section is formed. Estimated 70-80 percent of the T23 sales come from drifting.

Figure 3.7. *Customer process in drifting and tunneling (Olsson, R. 2012).*

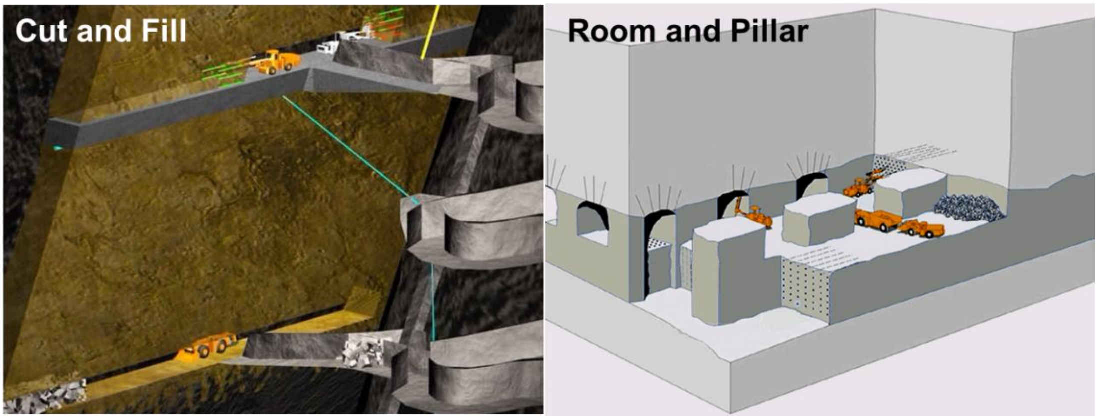

Figure 3.8. *Drifting applications: Ore mining (Olsson, R. 2012).*

Tunneling is used a lot in the construction of hydro power plants (Fig. 3.9). Tunnels are used to bring water from rivers or reservoirs to the turbines for power generation. Tunnels are also used for leading the water back to rivers after passing the turbines. Sometimes tunnels are used to divert rivers during the construction of dams.

Figure 3.9. *Tunneling application: Construction of hydro plants (Olsson, R. 2012).*

Figure 3.10. *Tunneling application: Highway, railway and metro tunnels for infrastructure purposes (Olsson, R. 2012).*

Tunnels are also used for the supply of drinking water, collection and disposal of sewage water as well as water for irrigation purposes. World's longest water supply tunnel is 120 km (Päijänne tunnel in Finland). Tunneling is also used a lot for preparation of underground facilities like oil and gas storage caverns, sport facilities, metros, laboratories and archives (Fig. 3.10 and 3.11).

Figure 3.11. *Tunneling application: Rock caverns for infrastructure purposes (Olsson, R. 2012).*

3.3 Bench drilling

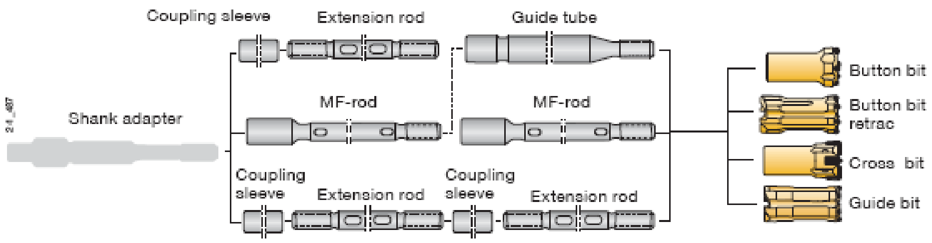

Figure 3.12. *Different tools used in bench drilling (Top Hammer Drilling Tools Product Catalog).*

Bench drilling is a big business for top hammer tools (Fig. 3.13). Quarrying forms a big part of it. Quarrying is when small stones, gravel, is made out of rock. Holes are drilled into the rock by adding rods together one after another during the process of drilling deeper. Then bigger pieces of rock are blasted off from the solid rock and crushed and screened. Sandvik Group offers also machines for crushing and screening operations. In the world exist a lot more quarries than mines. Quarrying business is under business area construction in Sandvik Group.

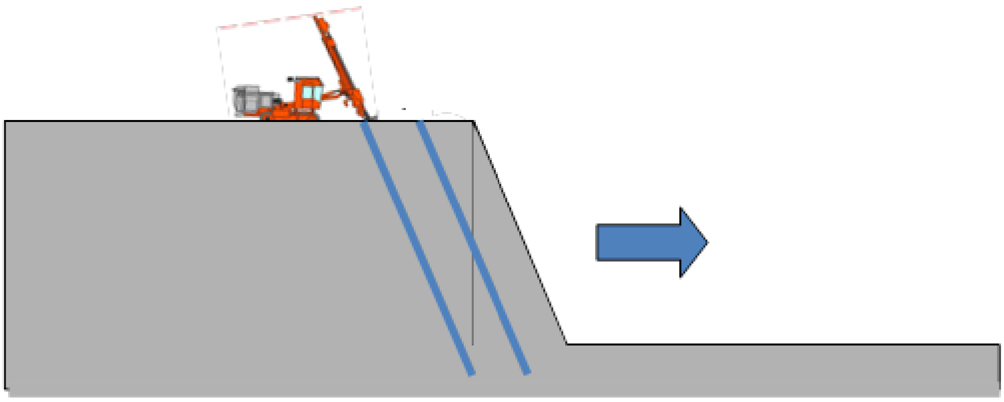

Figure 3.13. *Inclined bench drilling, most common way in bench drilling (Olsson, R. 2012).*

T21, T22 and T26 (Fig. 3.12) are used also in small open bit mines. Drilling and blasting operations are similar to ones done in quarries but purpose of open bit mines is to mine ore. Around 25% of sales for each of these minors come from open bit mining business. This is under mining business area in Sandvik Group.

In bigger open bit mines are Down-The-Hole (DTH) and rotary tools used. These tools are not in the scope of this study.

Demand for T21 stays steady whereas demand for T22 increases. Production volume in pieces in PU Sandviken for T22 was almost double compared to T21 in 2011.

3.3.1 Minor group T21

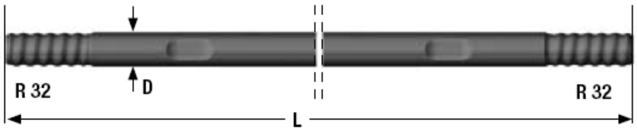

Figure 3.14. *Extension rod (Larsson, K. 2012).*

Product is extension rod and high frequency hardened (Fig. 3.14). Material flow on the shop floor is T21.

Product is mainly used in construction drilling in quarries. Extension rods are attached to each other with coupling sleeves.

3.3.2 Minor group T22

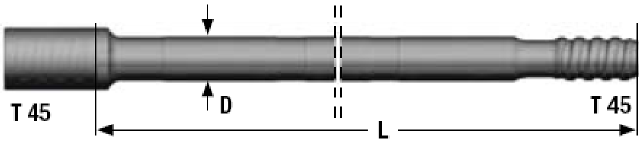

Figure 3.15. *Long MF –rod (Larsson, K. 2012).*

Material flow on the shop floor is T22 and the product is long (Fig. 3.15).

T22 is similar product as T21 but more sophisticated. T22 has number of benefits over T21. It is more suitable for mechanized rod handling system, has increased penetration due to higher energy efficiency through the connection and produces straighter holes since the play in the treads has been reduced to half. It also decreases the number of items needed to be stock by customer since no coupling sleeves are needed.

On the minus side, the T22 is more demanding for the operator who operates the drill rig. He needs to be more skilled.

T22 is premium product compared to T21. Sandvik product area Rock Tools is positioning itself as a premium tools provider. The company is pushing the product and demand for T22 is increasing.

3.3.3 Minor group T26

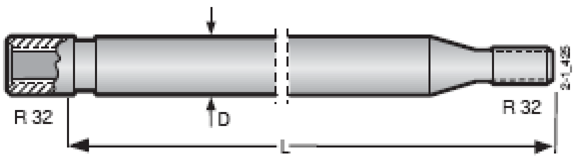

Figure 3.16. *Guide tube (Top Hammer Drilling Tools Product Catalog).*

Material flow on the shop floor is T26 for the product (Fig. 3.16).

Product is used in open bit mining and construction to improve hole´s straightness. When drilling long holes the string of rods tends to start deviate from the straight line. It starts to follow the path inside the rock which is easiest for it to follow. Path, in which the rock is softer, has already cracks, etc. If drilled holes are not straight it disturbs blasting. Demand of the product follows sales of T22 and T21.

3.4 Long hole drilling underground

3.4.1 Minor group T26

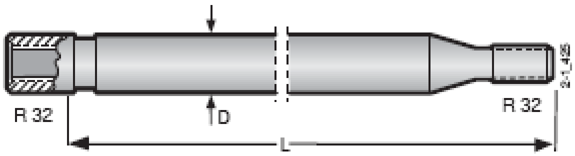

Figure 3.17. *Carburized guide tube (Top Hammer Drilling Tools Product Catalog).*

When the product is carburized it follows the material flow T25 on the shop floor.

There are three levels of hole straightness in long hole underground drilling. The first is when only T28 MF –rods are used. The second is when T28 –MF rods are used plus guide tube at the beginning of the string and the third is full string of T25 drill tubes. The third one is producing straightest hole. In that one, there is more striking surface in connection point of two rods which conducts the force better.

Some of the products in minor group T26 (Fig. 3.17) are carburized and some are not. When a T26 product is carburized it is used in underground mining and longest length is 1.8 meters. Drilling is often done 360° vertical. When a T26 product is not carburized it is used in construction and surface mining. Length of the rod is 3.1 meters or more.

3.4.2 Minor group T28

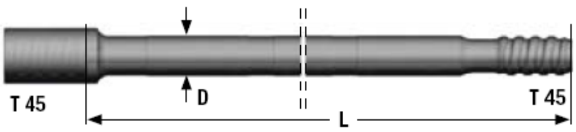

Figure 3.18. *Carburized MF -rod (Larsson, K. 2012).*

The product (Fig. 3.18) follows material flow T28 on the shop floor.

T28 has similar characteristics as T22 but is carburized to stand better the rough conditions of underground drilling. It is also shorter than T22 because underground the work space is small. The product is used only in underground mining.

Demand of T28 is increasing more than demand in generally in rod products.

3.4.3 Minor group T25

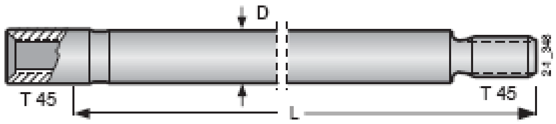

Figure 3.19. *Carburized drill tube (Top Hammer Drilling Tools Product Catalog).*

The product (Fig. 3.19) has material flow T25 on the shop floor. Around 85 percent of volume on the material flow T25 consists of minor group T25 products and 15 percent of carburized T26 minor group products. Applications are similar than in T26 carburized but hole diameters and specially length are bigger.

4 PRODUCTION ENVIRONMENT

4.1 Characteristics of demand on product group level

Nine product groups (referred as minor groups in chapter 3. Products) are produced in rods production in Sandviken. Demand variability is high. This can be seen from the figure 4.1. Order intake for the last five years is presented from the point of view of stockroom 12. Demand raw data is from Supply Chain IT –systems. The data is exracted by Supply Chain IT –processes Specialist John Salyer.

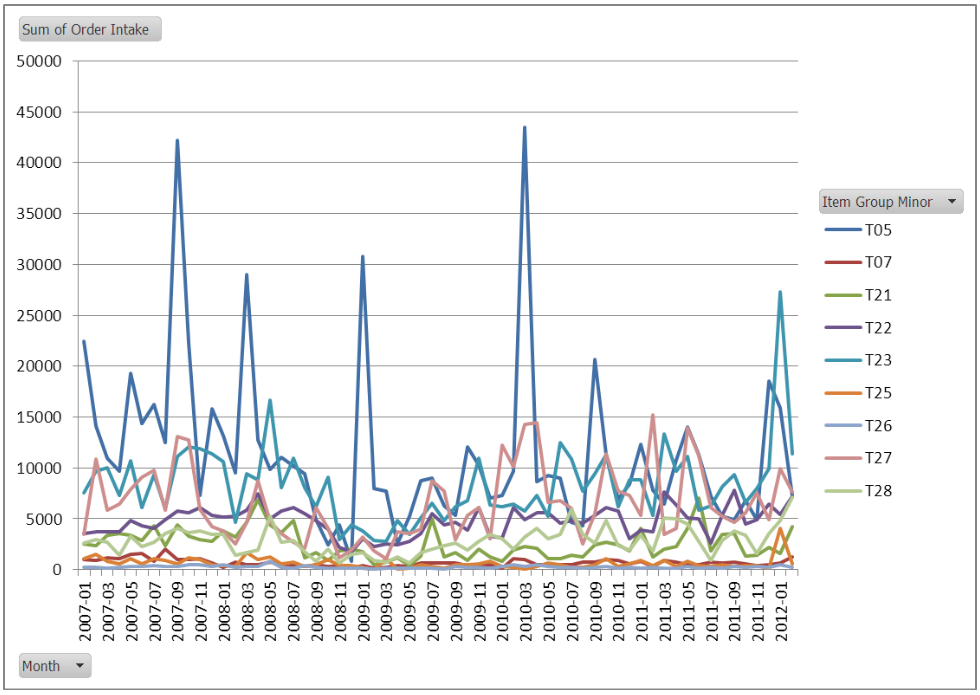

Figure 4.1. *Five years order intake from the point of view of stockroom 12.*

In normal natural situation demand patterns are formed from direct customer orders and orders released by ROPs (Re-Order Point) in regional warehouses. Demand here is customer Order Intake (OI) from the point of view of stockroom 12. Stockroom 12 is the finished goods inventory in production unit Sandviken. During 2011 around 25 percent of the OI was direct customer orders and 75 percent was generated by ROPs in regional warehouses.

Based on the stock levels in stockroom 12, are production orders generated to the production unit. The signal when a production order should be generated is mainly a ROP in the stockroom12. ROP has forecasting component in the algorithm but it is not been utilized. ROP is moving by historical demand data which algorithm utilizes. Without forecasting component the algorithm is not adding significant value to the production´s capabilities to respond to demand changes.

Demand curves shown in the figure 4.1 are not fully natural for all five years. During the time period demand-and-supply-balancing practice was started by PwC Consultancy Group (PriceWaterhouseCoopers) and it changed the demand patterns.

What can be seen is that started practice didn´t decrease variability noticeably when looking at figure 4.2. Backlog and material flow out from the factory are not noted in the picture. Variability in production and supply chain means costs and decreased supplying capacity. The practice controlled markets from selling more than what was production capacity. During that time demand was higher than production capacity.

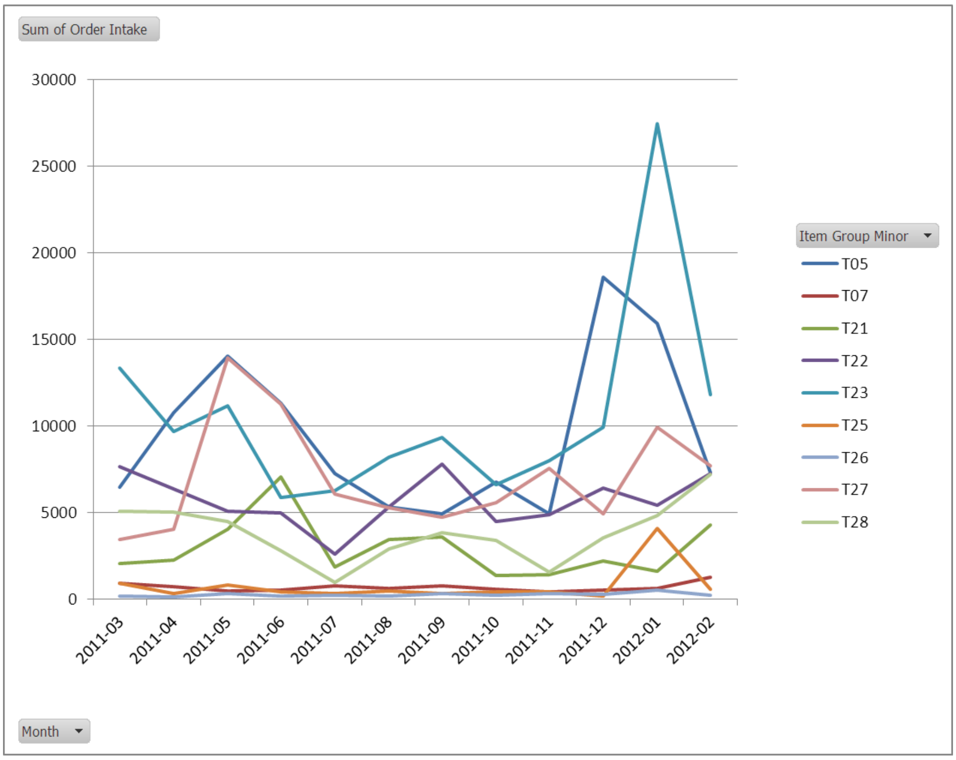

Figure 4.2. *Demand in pieces during last year, 2011.*

When looking at the demand on the figures 4.1 and 4.2, it is crucial to notice that it is in pieces. It is not in Cost Of Goods Sold (COGS), not in the sum of needed manufacturing operations time or in factory internal lead time. For example product ground T05 which here has highest variability and highest demand in pieces, don´t take a lot of manufacturing time and capacity on the shop floor. It is a small product with only few fast manufacturing operations done on it on the shop floor.

Still its variability affects the material flows of other product groups on the shop floor as it shares resources (internal shot blasting, external shot peening, labeling&charging and surface treatment) with them. T05 was only an example. The situation is the same for all the nine product groups. All of them are using shared resources.

Variability of one product group affects material flows of others. On the shop floor there are all together 11 shared resources.

4.2 Variability in production and supply chain

Variability in production and supply chain means costs. Variability often increases along with the length of the supply chain. This increase in variability which exists in supply chain is also known as tail whip effect. Key for lean and profit making supply chain and production is minimized variability.

Order intake for the production unit consists of direct customer orders and customer orders generated by ROPs in regional warehouses. During 2011 around 25 percent of the OI was direct customer orders and 75 percent was generated by ROPs in regional warehouses. Figure 4.3. illustrates how variability increases in the supply chain in which production unit Sandviken is connected. Functions which generate variability are from left to right; Real customer orders, regional warehouse ROP, stockroom 12 ROP, PU production planning and production process, supplier and supplier´s supplier.

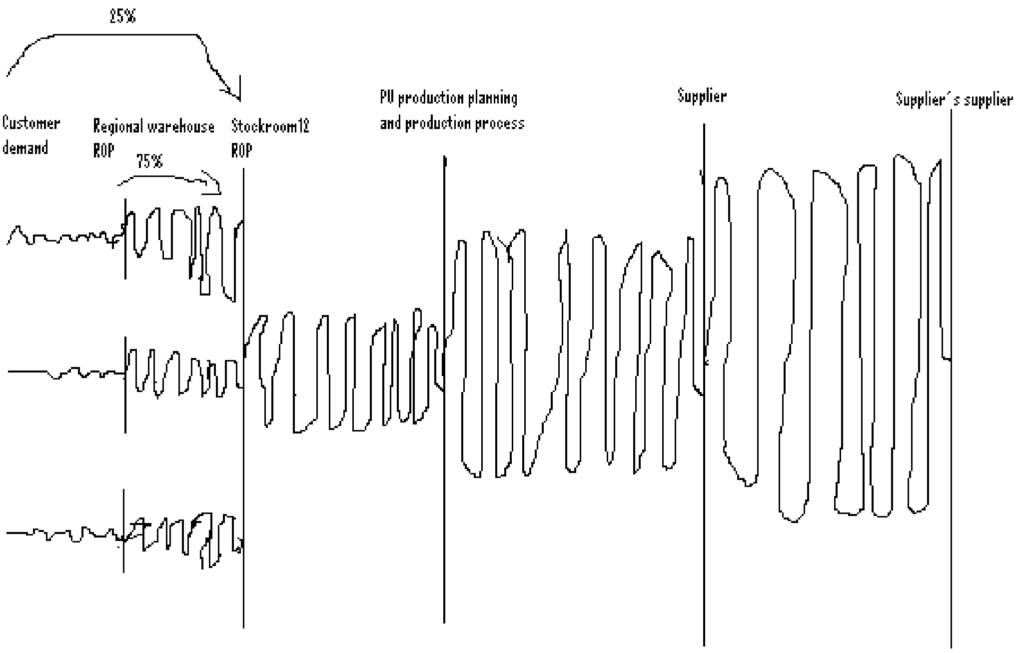

Figure 4.3. *Tail whip effect on the supply chain in which PU Sandviken is a part.*

It is good to notice that the variability PU sends towards suppliers can be seen behaving same way towards warehouses in regions and customers. Because PU is not feeding a steady flow of products towards regional warehouses and customer warehouses, those warehouses have to have higher stock levels meaning higher ROPs. Warehouses are forced to keep higher safety stocks to make sure availability of the products. What is the variability of the material flow out from Sandviken and is it behaving like mentioned above, was not able to be confirmed because of difficulties to obtain the data.

4.3 Material flows and shared resources

The production unit has complex material flows with many shared resources. On the shop floor there are 11 shared resources. Resources in this context mean manufacturing operations on the shop floor. Resources can be seen on the figure 4.4.

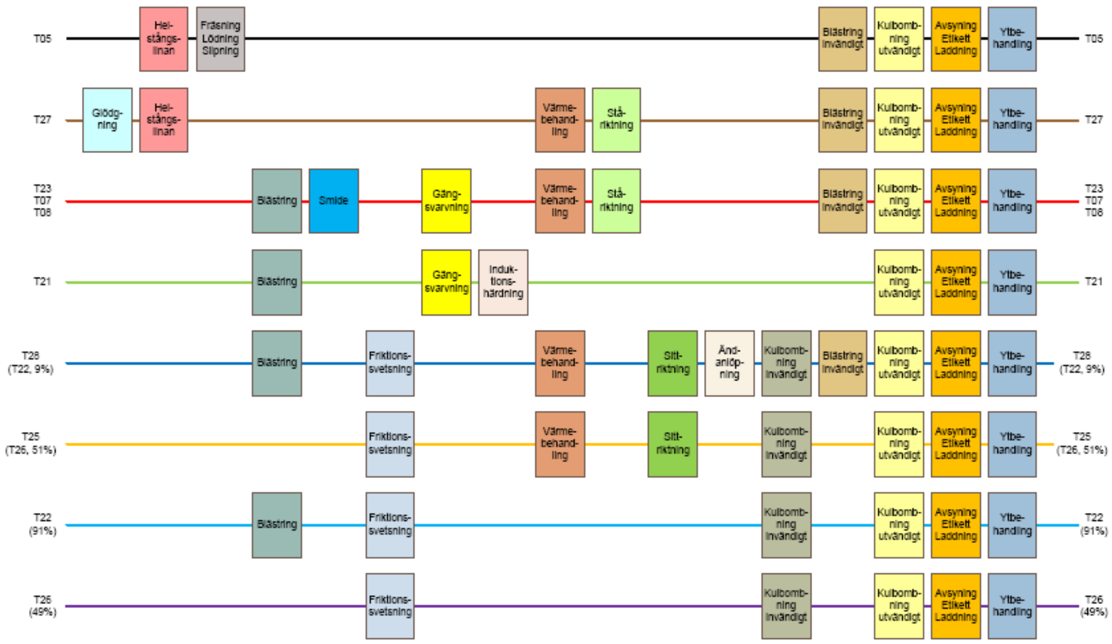

Figure 4.4. *Shared resources on the shop floor.*

On the figures 4.5 and 4.6 is shown how physically the material flows go on the shop floor. The width of the line presents subjective estimate, based on combination of number of pieces, COGS and manufacturing time, of the importance of a material flow for the organization of work on the shop floor.

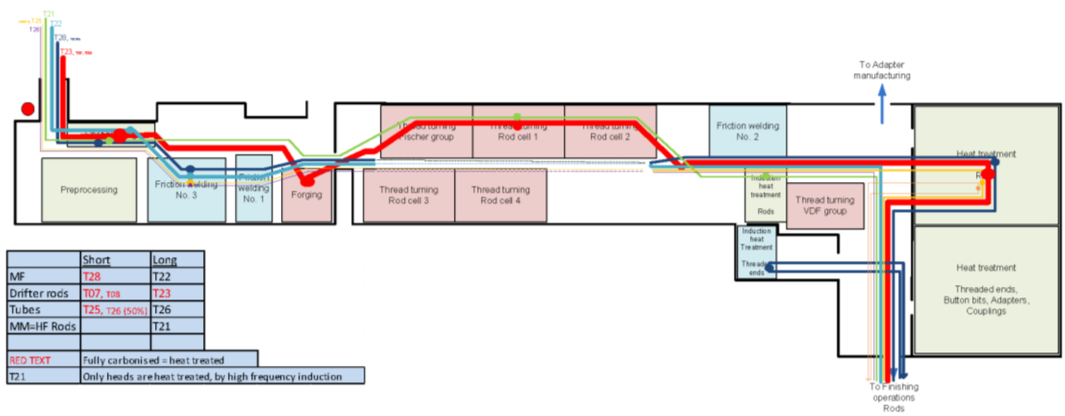

Figure 4.5. *Starting part of the most material flows.*

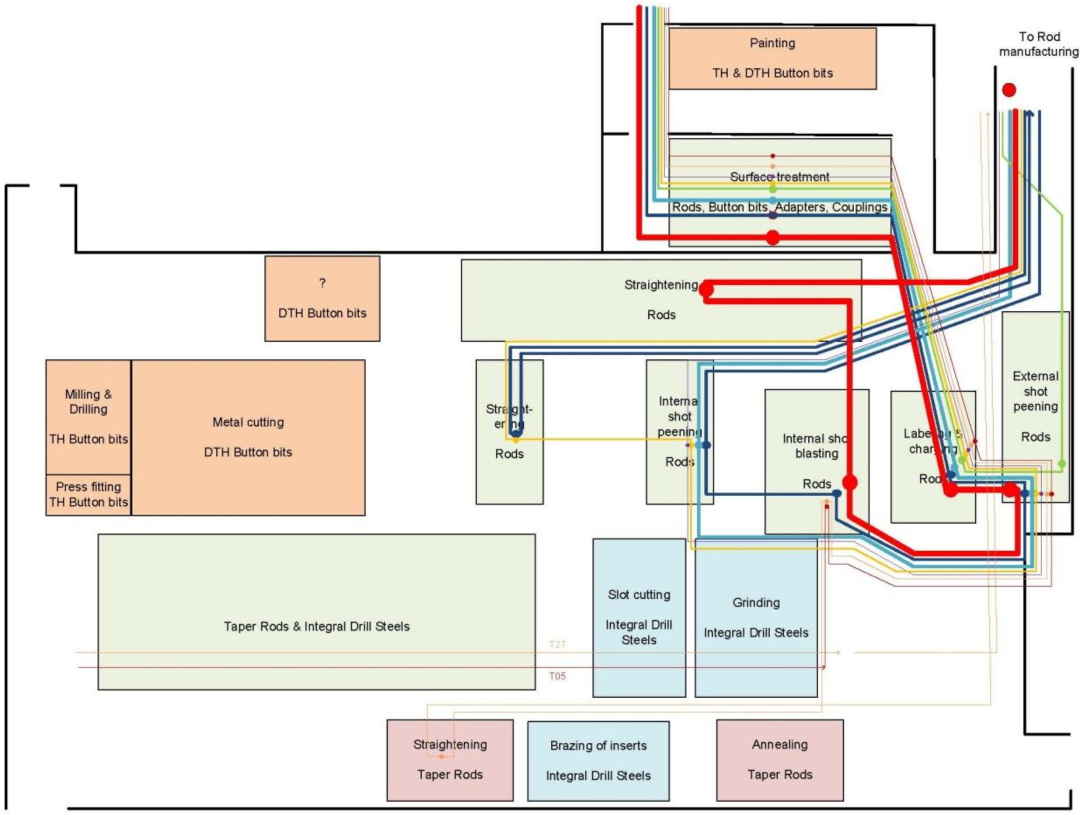

Figure 4.6. *Ending part of the material flows.*

4.4 Characteristics of demand inside a product group

When manufacturing times vary a lot inside a product group, should the item mix be noted already in rough cut capacity planning. If demand variability on the product group level together with item mix variability is not considered, work on the shop floor is going to be organized wrong. Materials don´t flow smoothly and there is too much or too little capacity in wrong places.

The data on the following charts is from production IT -system COOL. When looking at the charts it is good to keep in mind that the data is not well maintained.

Another issue that is good to note is that times include heat treatment. For heat treatment, times in production IT –system vary from 3 – 35.1h / 100 products. Also inside a product family there is variation. For example in T23 times for heat treatment vary between 9.5 – 17.5h /100 products. Still, like descripted in the section 4.5. Heat treatment, capacity wise for all the products has the function capacity of four hours per product. To get a more accurate picture of the situation should the data be cleaned in a way that all heat treatment times are replaced by four hours.

Never the less, give following charts a hint of what is the situation.

4.4.1 T23

T23 is considered by the PU management as the most important product group. Difference in manufacturing times is small as seen on the figure 4.7. Data is from production system COOL. On the horizontal axis there are items and in vertical hours.

The time on the vertical axis is formed by summing standard manufacturing times which a batch of 100 similar items takes in different manufacturing operations on the shop floor. For example 7324-4124-20 goes through following operations in the manufacturing process; shot blasting, forging, thread turning, heat treatment, straightening, internal shot blasting, external shot peening, inspection&labeling&charging and surface treatment.

Standard manufacturing time in case of PU Sandviken is formed as shown on the formula 1. T_{std} is standard manufacturing time, T_{pcx} is process-/cycletime and U is utilization rate. As can be seen, utilization rate is already included in the standard times.

$$T_{std} = T_{pcx} \times U \qquad (1)$$

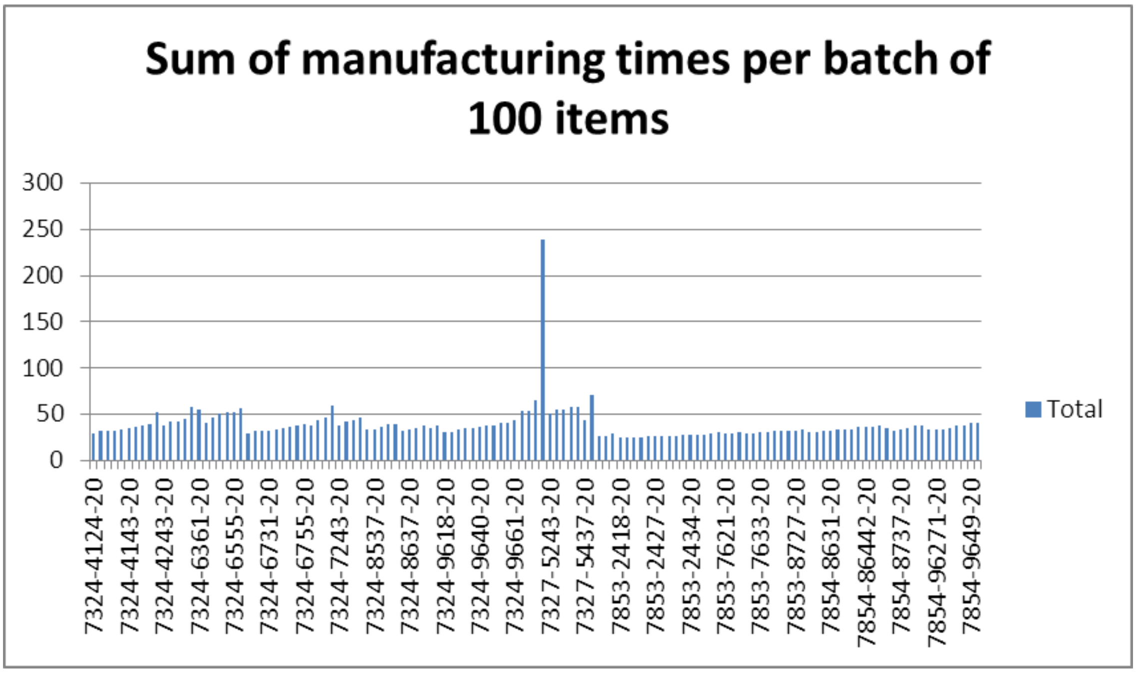

Figure 4.7. *Difference in manufacturing times of products inside product group T23.*

When doing capacity planning, item mix variability don´t have a lot of meaning. Demand inside the product family is also spread out pretty evenly. 30 products out of 64 form 80 percent of the demand. If wanted, in rough capacity planning can be one average time used for all of the products.

4.4.2 T28

Difference in the manufacturing times can be seen in the figure 4.8 but there are inconsistences that prohibit us from making conclusions.

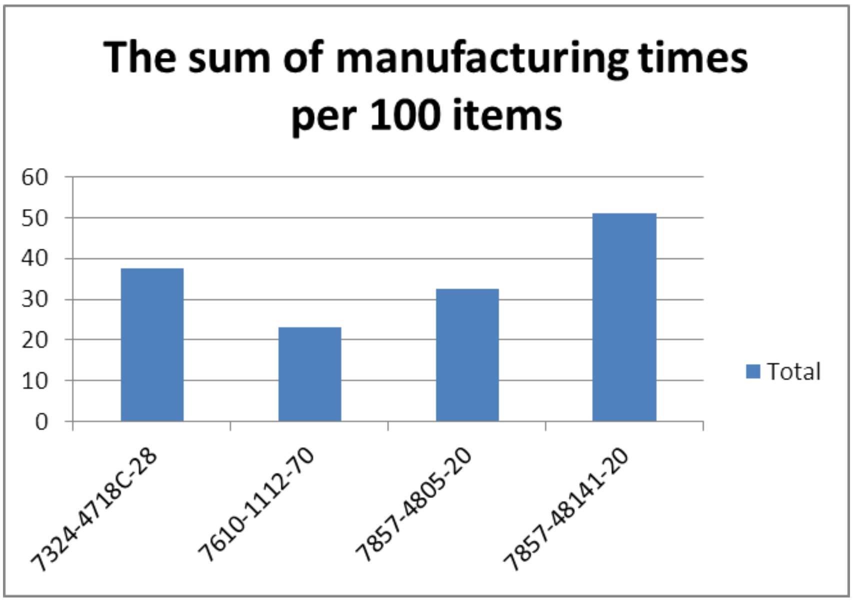

Figure 4.8. *Difference in the manufacturing times inside a product group T28.*

In the production system COOL only four items have standard times. In the period of March 2011 – February 2012 17 items were produced as seen in the table 4.1. Grand total is sum of OI on that period.

Table 4.1. *T28 products produced in March 2011 – February 2012.*

ITEMS	GRAND TOTAL
7324-4715C-20	7315
7325-7715C-20	5526
7324-4718C-20	5257
7853-5118-20	5186
7324-4712C-20	4774
7853-5115-20	3913
7325-7718C-20	3280
7853-5112-20	2716
7853-51083-20	2263
7326-5515C-20	1890
7326-5518C-20	1222
7324-4709C-20	656
7326-5509C-20	655
7327-4718-20	379
7325-7712C-20	326
7853-5109-20	127
7857-48141-20	14

This inconsistency prohibits us from making conclusions. If variability in manufacturing times in product group T28 is in general as big as suggested by the four items, also the item mix of T28, not only demand, has to be noted when doing rough cut capacity planning. Variability in T28 affects other material flows through shared resources which it has.

Another question is how product cost calculation can be done if standard times are not defined.

Interesting would be also to study how currently P&C for the product is done. Especially, how the execution and control is done. In general, is production planning department for example using mixed scheduling of fast and slow products to create daily balanced flow to minimize variability if material flows are currently considered individually and not in interaction which other flows. Due to the lack of time from organization the issue was not able to be studied.

4.4.3 T25

Difference in the manufacturing times can be seen in the figure 4.9.

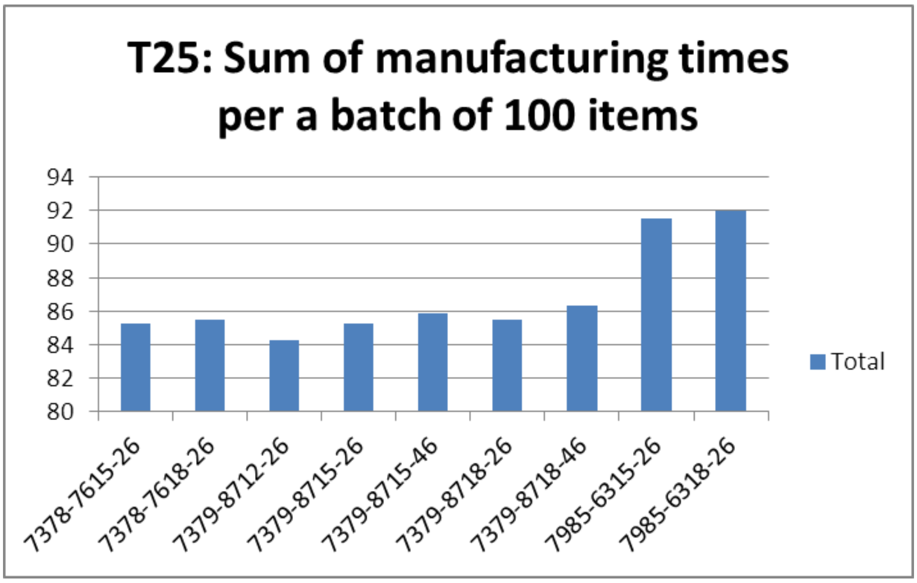

Figure 4.9. *Difference in the manufacturing times inside product group T25.*

During March 2011 – February 2012, 10 items were produced. Four items out of ten form 88 percent of the OI volume. These four items have a sum of manufacturing times between 84 and 86h for a batch of 100 items. Same standard time for every product in the product group can be used when doing rough cut capacity planning. Conclusion is that item mix don´t have to be necessarily considered in rough cut capacity planning.

Even though item mix doesn´t have a great meaning, T25 cannot be excluded in the production rough cut capacity planning because it has shared resources. Demand variability in material flow T25 affects capacity of other material flows.

4.4.4 T27

Difference in the manufacturing times can be seen in the figure 4.10.

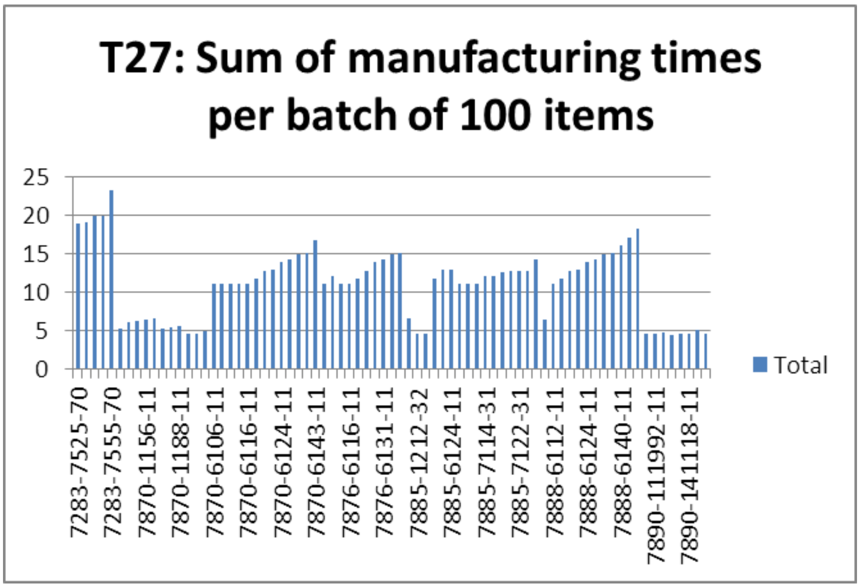

Figure 4.10. *Difference in the manufacturing times inside product group T27.*

During March 2011 – February 2012, 7 items out of 40 formed 81 percent of OI volume. Still item mix should be considered in rough cut capacity planning because variability in manufacturing times is really high. In case of T27, manufacturing times vary also inside the seven high movers. Variation is between 6.6h and 12h per batch of 100 same items. So capacity requirement can be sometimes double compared to another high mover.

Like in all the product groups, monthly variability exists in OI volume ratios of T27. As a theoretical example, one month 10 percent of products form 80 percent of OI and another month 30 percent form 80 percent. In general for all the product groups; during the years as environment and customer needs change and new products come in and old go away, can OI volume ratios change in large scale.

4.4.5 T22

Difference in the manufacturing times can be seen in the figure 4.11.

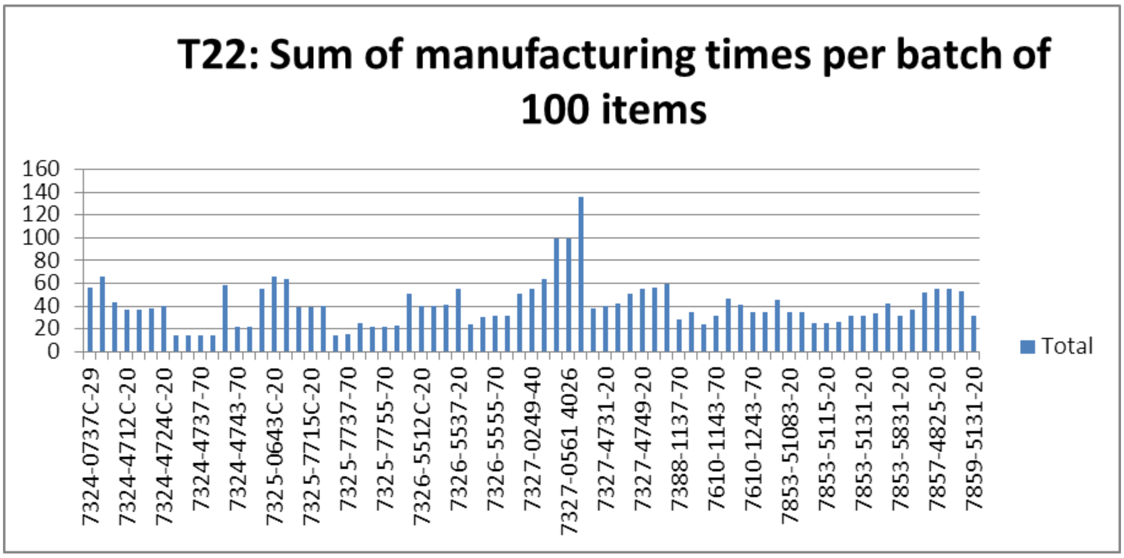

Figure 4.11. *Difference in the manufacturing times inside product group T22.*

During March 2011 – February 2012, 6 items out of 41 formed 82 percent of OI volume. Item mix should be considered in the rough cut capacity planning because variability in manufacturing times is really high.

4.4.6 T07

Difference in the manufacturing times can be seen in the figure 4.12.

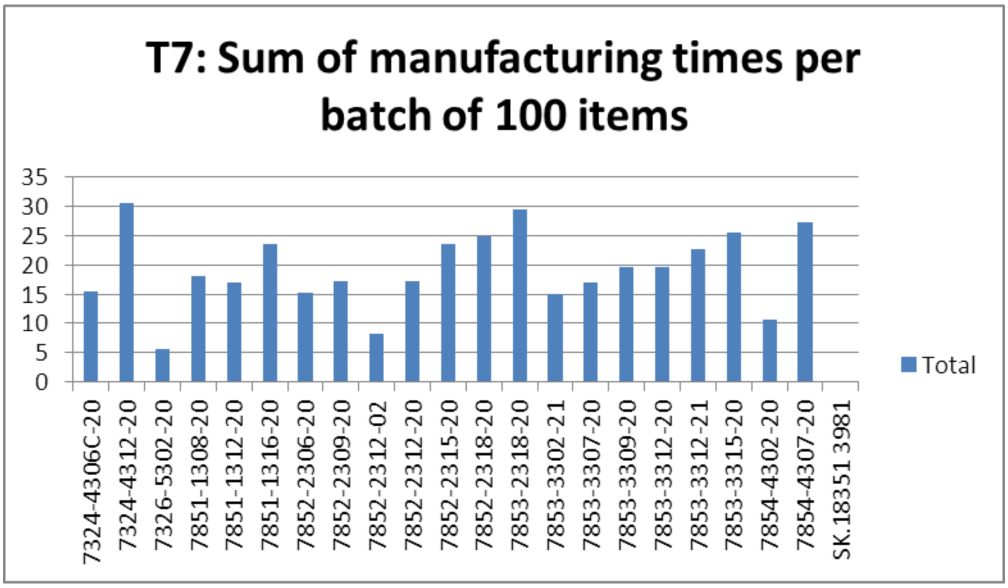

Figure 4.12. Difference in the manufacturing times inside product group T7.

During March 2011 – February 2012, 11 items out of 23 formed 81 percent of OI volume. Demand was distributed evenly among products but monthly demand variability in a single product level was high. Variability in the manufacturing times is also high. Item mix should be considered in the rough cut planning.

4.4.7 T21

Difference in the manufacturing times can be seen in the figure 4.13.

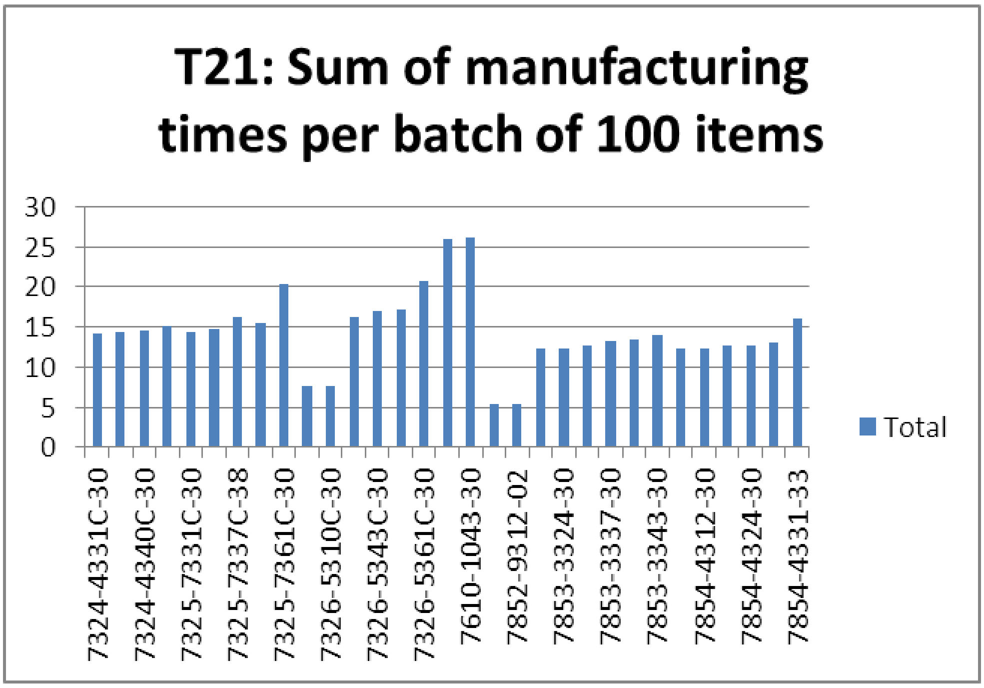

Figure 4.13. *Difference in the manufacturing times inside product group T21.*

During March 2011 – February 2012, 5 items out of 20 formed 84 percent of OI volume. Manufacturing times vary moderately inside the five high movers. Variation is between 12.2h and 16.2h per batch of 100 same items. So, for example daily capacity requirements in a manufacturing operation on the shop floor can vary 30 percent depending on item mix of that day.

Conclusion is that it would be beneficial to consider item mix in rough cut planning but using one standard time for all the products would not be catastrophic.

Still it is good to note that even though the item mix doesn´t have a great meaning; T21 cannot be excluded in the production rough cut capacity planning because it has shared resources. Demand variability in material flow T21 affects the capacity of other material flows. This is the same for all the material flows. Capacity of a material flow is depended on the load of other material flows.

4.4.8 T05

During March 2011 – February 2012, 14 items out of 61 formed 82 percent of OI. Production of product family T05 is been planned to be moved to another factory. Data for manufacturing times for the product family is missing but can be obtained from PU´s Production Specialist Bertil Norgren if needed in the future studies.

4.4.9 T26

Difference in the manufacturing times can be seen in the picture 4.14.

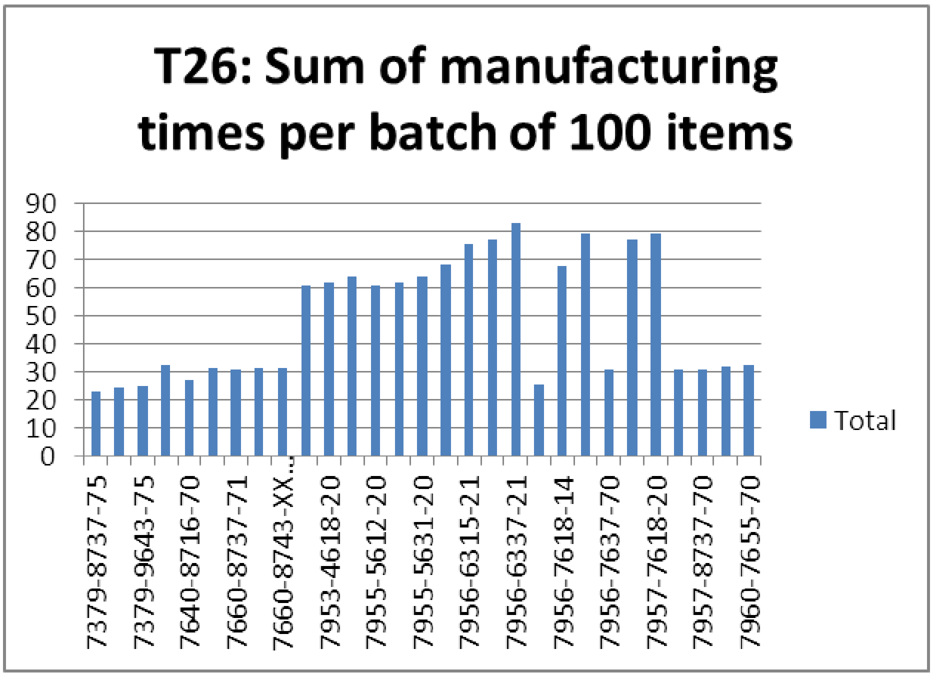

Figure 4.14. *Difference in the manufacturing times inside product group T26.*

During March 2011 – February 2012, 8 items out of 22 formed 82 percent of OI volume. Item mix should be considered in rough cut capacity planning because variability in manufacturing times is high.

4.5 Heat treatment

The first priority for the production planning and control and PU management should be maximizing through put volume of the whole factory. The priority should not be high utilization rates in every function. It would lead to suboptimizing and disturbed material flows and result would be poor profitability. Second priority is to organize and plan work and investments in a way that an investment which is more expensive than others is often the bottleneck. Of all the operations on the shop floor in PU Sandviken, the heat treatment is the most expensive investment.

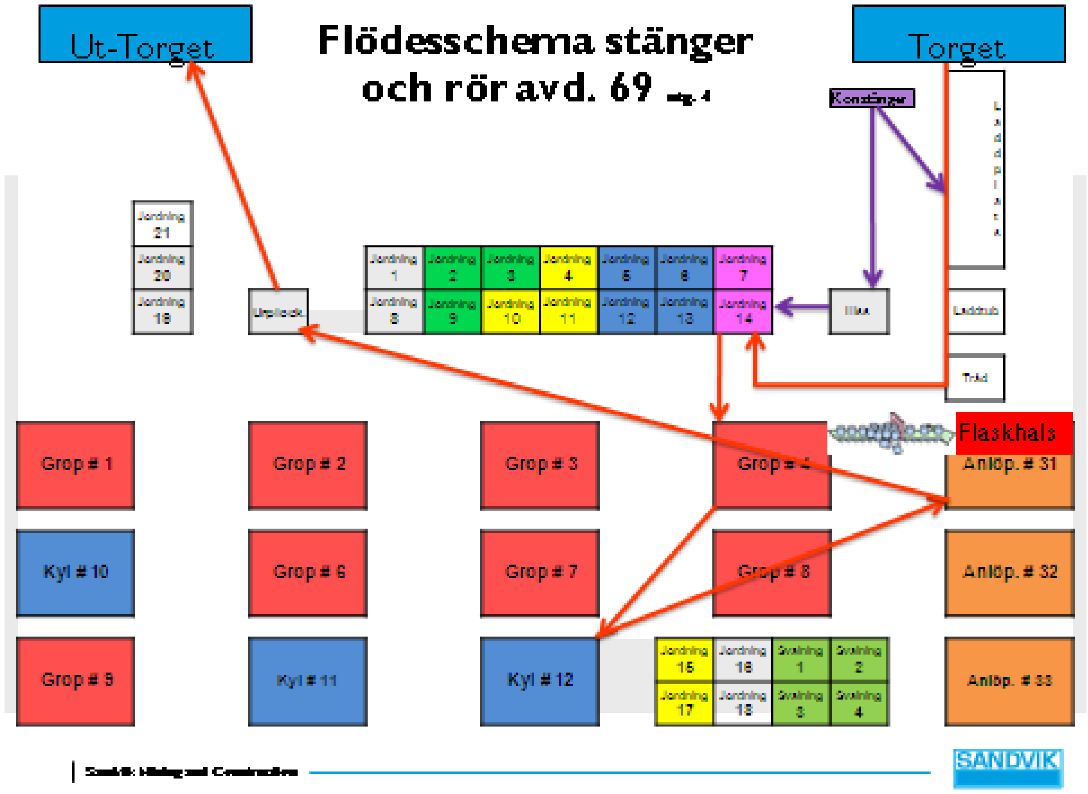

Figure 4.15. *Furnace function´s internal material flow (Kaisto, M. 2012).*

There are three operations done inside the furnace function in following order (Fig.4.15):

- Carburizing (uppkolning)
- Hardning (härdning)
- Tempering (anlöpning)

There are eight carburizing furnaces, three hardening silos and three tempering furnaces. A crane is used to load batches to furnaces.

4.5.1 Through put capacity parameter of the function

Scheduling internally in the furnace function is done by tempering. It is the last operation and is a bottleneck considering that it has limited capacity compared to the other two operations. This makes it the guiding operation. Material flow through other two functions is scheduled so that it would maximize the use of tempering operation´s capacity.

➔ In rough-cut capacity planning the std. operation time of the tempering operation for a part is to be used as a capacity parameter for the whole furnace function.

All the products (rods) have the tempering operation time of four hours.

4.5.2 Current scheduling process in the heat treatment

Furnace function has its own scheduling practice as seen on the figure 4.16.

SANDVIK

Isättningsschema VBH 69

Vecka: 1212

Hgrp	Isättning	Mån	Tis	Ons	Tors	Fre	Lör	Sön	
Extraruta	00:00	23		23					
T27	00:30	27	27	27					
T27	01:00	27	27	27					
T27	03:00	27	A	27					
T22.28	03:30	UB	28	28					
T22.28	04:30	22	28	28					P5/04:30
T04.07.08.23.	05:00	P11	23	23					P3/07:00
T04.07.08.23.	05:30		23						
T04.07.08.23.	07:00	22	23	23					
T25.26"'	08:00	25	26	25					
Extraruta	08:00	23	23						
T04.07.08.23.	09:30	23	UB	23					
T27	11:00	27	23	27					MUB=mutterbrist
T22.28	11:30	28	28	28					BB=brickbrist
T04.07.08.23.	12:00	UB	23	T					MB = Materialbrist
T25.26"'	13:00	25	25	26					UB = Ugnsbrist
T22.28	14:00	UB	28	22					BL = Bara långt Material
T04.07.08.23.	15:30	23	23						
T22.28	16:00	28	28						T = Tidsbrist
Extraruta	17:00								
T04.07.08.23.	17:30	23	23						A = Annan orsak 1,2,3.
T25.26"'	19:30	26	26						1
Extraruta	19:30								
T04.07.08.23.	20:00	23	23						3
T04.07.08.23.	22:00	23							
T25.26"'	23:30	26	25						T27 Konstänger

T22,28 program G38 Isättning på rör-plats — T22,28 MF stänger

"' T25,26 program G39 Isättning Mån-Sön 09:30, 14:30, 21:00 eller 01:00 .Får användas till MF-stänger — T25,26 RÖR

"""T04.07.08.23. P3 00:30/08:00 /09:30 /12:00 /14:00/18:00/19:30/22:30 — T04.07,08,23 Sexkant

P11 Om ni inte kör P11 så kör 6-kant istället

Figure 4.16. *Function´s internal scheduling for a month showing dedications of furnaces to specific material flows (Kaisto, M. 2012).*

Every month the function gets monthly production plan on minor group (material flow) level. Total number of pieces is specified. For example, on April is going to be 3000 pieces of minor group T23 products been produced. Inside minor groups between the items the operation times vary. Monthly production plan doesn’t tell item mix.

Scheduling is done by dedicating certain furnaces (capacity) to specific minor group on that month. There are eight carburizing furnaces in the function. Monthly production plan of all the minor groups together is examined and then the eight furnaces divided between the material flows. Function is running 24h/7. In steady intervals is a new batch put in to a furnace.

4.5.3 Effect of item mix on capacity

The furnace function has with current setup enough flexibility to drive all kinds of different daily item mixes. There is build-in free time in the heat treatment´s internal scheduling process.

- For example in T23, for the short rods would be five hours and less enough and for the long rods (over 1.8m) roughly the time of seven hours is needed. All products of T23 are though scheduled with the operation time of seven hours.
- After hardening operation can a product wait maximum of four hours before it has to be moved to the tempering.

➔ With the current furnace function setup and function´s internal scheduling practices, coming item mix has minimal or no effect on the function’s capacity.

4.6 Planning-End-To-End Project

Consultancy group PwC is driving a change in the supply chain in which PU Sandviken is connected. They are doing distribution network transformation and side project to that is a project called Planning-End-To-End, PETE. The project continues to develop further the demand and supply balancing practice which was started during 2011. It aims to renew the S&OP practices and some structures and teach the organization how to use forecasting more effectively. Tool is developed to help in utilizing forecasting better.

It is unsure whether the PETE project group has understood that PU Sandviken has a production environment which has moving bottlenecks. What is production capacity of PU Sandviken depends on item mix and demand. It is negotiable where the bottleneck will be. It is only a question of balancing between costs and customer satisfaction. This is discussed more in detail in chapter 2.5 Sales and Operations Planning. Do we want to aim for the best cost – customer satisfaction ratio or are there some other values which are important for the management of product and business area. That depends on the business strategy and how in it is the role of the product area seen. Is Rock Tools for example mainly a service for the customers and money is been made by selling drill rigs.

4.7 Chapter summary

4.7.1 Challenges generally in the production unit

The factory produces around 400 items and demand between items is distributed evenly. By evenly in these case means that few product groups follow 20/80 –rule. 20% of items inside the product group form 80% of the volume. Material flows on the shop floor are the same as product groups. Monthly demand variability is high. Raw material price forms significant parts of the value of a finished good. Value added inside the factory is medium. Material stocks including WIP –stocks should be kept to minimum. Size of the products is also rather big. Batches between shop floor operations are moved by cranes or forklifts.

Material flows inside the factory are complex. The factory has multiple shared resources. Bottlenecks on the shop floor are moving depending on demand and item mix. Current planning and control practices in the factory don´t take this well into consideration.

Factory gets production orders based on the ROPs in the finished goods inventory, Factory doesn´t control finished goods inventory and doesn't have good visibility to stock levels which decreases operational space in production planning and decreases possibilities for the production planning to balance material flows on shop floor.

Shop floor workers don´t have work time bank which decreases capacity flexibility in shared resources on the shop floor. Possibilities to plan and organize work for smooth flow and maximum through put volume decrease.

4.7.2 Variability

In the chapter 4 were three kinds of variability highlighted. They came from the characteristics of customer demand and characteristics of product structure.

Variability coming from production process, like quality deviations and not standardized operations, was not discussed. These come from inside the production process.

The three highlighted variabilities come from outside the production process. These are input values. First, the production process, including P&C, should be developed to deal with these. Second can variability coming from inside the production process be looked at. Analogy can be drawn with house building. It is better first to build foundation and then start building walls. The highlighted variability is presented below:

- Monthly variability in demand in product group level.

  High monthly variability in demand existed as was seen the figure 4.1.
- Monthly variability in a single product level.

  Was common in many product groups that some months a product had no OI (demand) and some months it had three times or more the yearly monthly average.
- Variability in the manufacturing times inside a product group.

  Sometimes high variability existed even among high movers as seen in case of T27.

Meaning of item mix in production planning was discussed. Even though in those cases when an item mix does not have a great meaning, a product group cannot be excluded in the production rough cut capacity planning because it is sharing resources with other material flows. In every case demand variability in product group level in a material flow affects capacity of other material flows. This is the same for all the material flows. Capacity of a material flow is depended on the load of other material flows. In rough cut capacity planning all the material flows have to be considered together.

5 SOLUTION DEVELOPMENT

5.1 Concept for rough cut capacity planning

Most of the activities in a factory are based on production planning. It is a challenging task and has crucial effect on a factory´s profit making capabilities. Production planning department is also important source of information for a manager of a production unit when making long term decisions. Better information planning department can give a production unit manager, the better decisions he can make.

Sometimes production environment can be complex with a lot of variables. For example when production environment has many shared resources becomes production planning challenging. Material flows are interacting with each other and load of one material flow is affecting capacity of others. When doing capacity planning, the production system has to be looked as whole. This makes the calculations involved in making production plan too difficult for a production planner to do in his head. Tool is needed to do them. It is important to notice that not a single tool in world can replace the need for a production planner to understand the production environment and the process. When a production planner has this understanding, he can use tools correctly to his advantage. In that case can a tool give good answers and be helpful.

Production unit Sandviken has complex material flows and many shared resources. The result of the variability in demand in product family level and in item mix is a production environment which has moving bottlenecks. The bottlenecks can also temporarily exist in unusual places because of for example yearly maintenance of a machine, lack of spare part, accident, lack of raw material, etc.

Visibility on moving bottlenecks would be needed, not only during times of high demand, but also during recession. During the recession it can be even more important to know where, how many and what type of workers is needed in order to satisfy the market demand. When resulting bottlenecks from different work organization, item mix and demand are made visible, more accurate planning can be done. Hard lay-off decisions are sounder and a factory can make a profit and meet market demand also during recession.

There are many software providers who offer software for rough cut capacity planning. Usually it is a part of a bigger system. Even when buying only rough cut planning tool, these projects might turn out to be rather big because of multiple stakeholders. In every case, a buyer should first know deeply his production environment. Without this knowledge, it is a difficult to buy and build together with the software provider a suitable tool. One has to know what he is buying. Commercial software offer nicer visualization, some automation and user friendliness. All of this comes with the cost and difficulty to modify and improve the tool.

Tool build on an Excel will bring majority of the benefits, it is cheaper, faster to apply and easier to modify as knowledge of the production environment increases and improvement ideas start to arise.

5.1.1 Excel based rough cut capacity planning tool

To build a rough cut capacity planning tool, following is required:

- **A route/material flow** of every product, and what resources a product uses, are know
- **Standard times** on use of resources for a product
- **Item mix** (demand) under wanted planning period
- **Available capacity** of a resource and how is that capacity formed
- **Algorithm**, which does the math

5.1.1.1 Shop floor view

On the main view are visible material flows on the shop floor, individual resources and shared resources. On a resource box is first number a load in minutes and second is load compared to available capacity on percentage. The numbers are for wanted planning period, for example one month. In the figure 5.1 is part of the shop floor view showed. The structure of the whole view is similar to a material flow picture in the figure 4.4 presented in the chapter 4.3. Material flows and shared resources.

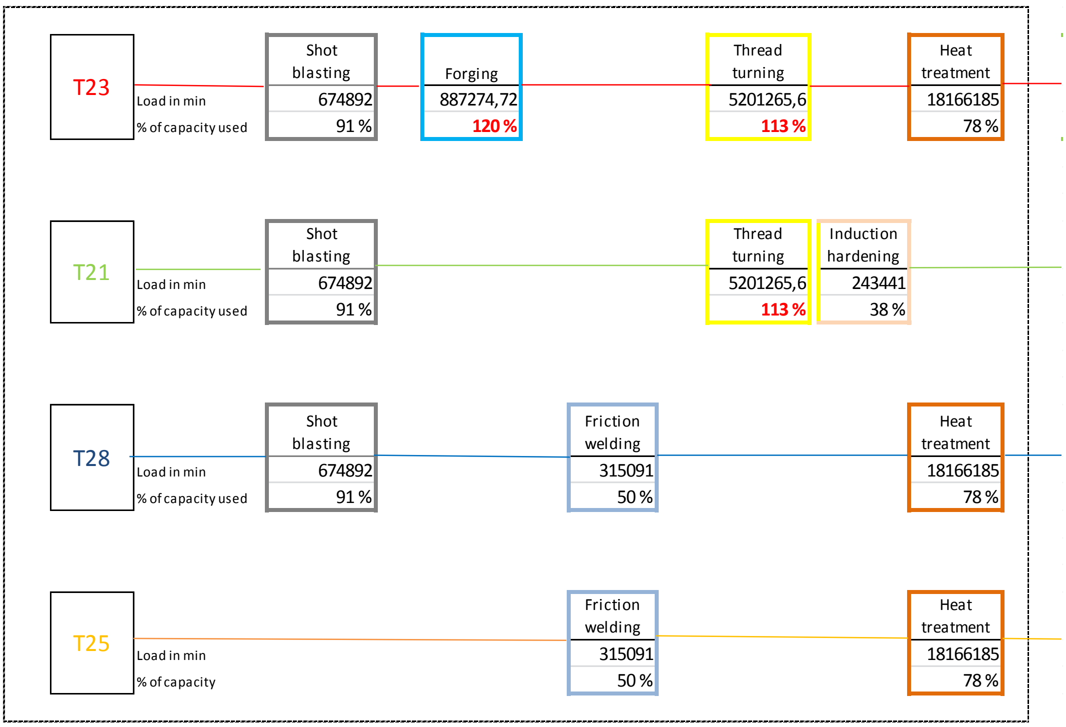

Figure 5.1. *A partial view of the shop floor view on the rough cut capacity planning tool.*

In the situation shown in the picture, few things are seen. Planned production plan cannot be executed with good delivery accuracy. Thread turning and forging are both bottlenecks and overloaded. Planned volumes or shop floor work organization has to be changed. There is too much capacity in the friction welding. People can be moved to thread turning or forging, maintenance work can be scheduled, schooling events for the friction welding team can be organized, methods development project in friction welding can be done, etc.

5.1.1.2 Standard times, routes and use of resources

As mentioned, a product´s manufacturing data is been managed in production system COOL. Standard times and routes are determined for most of the products. This data in the production system should be updated regularly, always when changes happen. Standard times on the other hand could be updated once a year. This keeps the tool accurate and helps to form more accurate calculations on productivity development.

In current situation, the times would have to be first cleaned. Utilization rate, meaning coffee breaks, tool maintenance, set up changes, etc., is already included in the times. Times should be only the actual processing times. Naming of activities on the shop floor should be standardized. For the capacity planning purposes, also heat treatment times would have to be cleaned away and replaced by four hours for each product which uses heat treatment. The reason for this is presented in the chapter 4.5. Heat treatment.

Needed manufacturing data is exported from COOL to the Excel based rough cut capacity planning tool. Table 5.1 shows a view in the Excel. Route and use of resources are shown.

Table 5.1. *A product´s route on the manufacturing process and use of resources.*

ITEM	OPNUM	OPERATION	STD.TIME /100 PCS
7853-2410-20	10	L$NGA PROD	0
7853-2410-20	20	BL#	0,3
7853-2410-20	30	SM R32 #ND	1,16
7853-2410-20	40	GL UPPSM #	0,72
7853-2410-20	50	GL 6-K #N.	0,72
7853-2410-20	60	P+FAS R32	0,89
7853-2410-20	70	P+FAS R25	0,71
7853-2410-20	80	SG R32	2,98
7853-2410-20	90	SG R25	3,08
7853-2410-20	100	F SPOLSP	0,6
7853-2410-20	110	V#RMEBEH	0
7853-2410-20	120	UKH#DI+PRH	9,5
7853-2410-20	130	F#ST#LLN	0
7853-2410-20	140	ASY	0
7853-2410-20	150	RIKT	3,03
7853-2410-20	160	BL# INV	0,36
7853-2410-20	170	KB UTV	0,64
7853-2410-20	180	ETI+LA	1,3
7853-2410-20	190	SR-BEH	0
7853-2410-20	200	M-GSK	0
7853-2418-20	10	L$NGA PROD	0
7853-2418-20	20	BL#	0,5
7853-2418-20	30	SM R32 #ND	1,16
7853-2418-20	40	S+SG	6,8

All operations of the product 7853-2410-20 are shown. The operations are labeled with numbers 10-200 in a column OPNUM.

5.1.1.3 Item mix under planning period

Effect of different item mixes and load on the capacity is made visible by the tool. Wanted load is put in to the tool. Load can be demand under certain period or other wanted number of different products to be produced. Time period can be one month or for example three years.

Time period cannot be less than one month. If it would be, then the logic in which order shared resources starts processing products would have to be noted. For example is a product with closest due date going to be taken first or a product which has the earliest starting day. Factory internal lead time is around seven days. When looking at time period less than one month this logic or let´s say behavior feature of material flows effect capacity.

Three years capacity study helps to see the investment and personnel needs. A representative item mix is formed based on the historical demand and set in to the tool.

Then that item mix is multiplied by three years and by forecasted increase/decrease rate in percentages during the time period. Available capacity in minutes is multiplied by three years. Future bottlenecks can be seen beforehand and proactively reacted before they turn into a problem.

T23		T21		T28		T25	
Item	**Load. pcs**	**Item**	**Load**	**Item**	**Load**	**Item**	**Load**
7324-4124-20	174	7324-4331C-30	1051	7324-4715C-20	1163	7379-8715-26	250
7324-4126-20	320	7325-7337C-30	1347	7325-7715C-20	999	7378-7618-26	75
7324-4128-20	330	7326-5337C-30	572	7324-4718C-20	616	7379-8718-26	221
7324-4131-20	1796	7324-4337C-30	352	7853-5118-20	356	7379-8718-46	
7324-4137-20	2972	7853-3324-30	430	7324-4712C-20	1123	7379-8715-46	40
7324-4143-20	2230	7853-3337-30	102	7853-5115-20	945	7985-6318-26	
7324-4145-20	0	7853-3331-30	152	7325-7718C-20	530	7378-7615-26	
7324-4149-20	3129	7325-7331C-30	208	7853-5112-20	422	7985-6315-26	
7324-4155-20	2158	7852-2312-02		7853-51083-20	720	7379-9637-75	
7324-4164-20	0	7325-7343C-30	3	7326-5515C-20	198	7379-9643-75	
	26	7326-5343C-30		7326-5518C-20	8		
7324-4243-20	26	7852-9312-02		7324-4709C-20	11		
7324-4249-20	30	7326-5361C-30	15	7326-5509C-20			
7324-4255-20	0	7854-4318-30	21	7327-4718-20	33		
7324-4261-20	0	7854-4312-30	3	7325-7712C-20	40		
7324-4264-20	38	7854-4331-33		7853-5109-20	16		
7324-6361-20	22	7854-4324-30		7857-48141-20			
7324-6531-20	119	7854-4331-30	3				
7324-6537-20	1483	7853-3343-30					
7324-6543-20	4648	7326-5310C-30					
7324-6549-20	296						
7324-6555-20	665						
7324-656400-2	0						
7324-6724-20	0						
7324-6726-20	0						
7324-6728-20	0						
7324-6731-20	2138						

Figure 5.2. *A partial view of the item mix view of the tool. Planned load in pieces in wanted time period. Here a monthly load shown.*

5.1.1.4 Available capacity

Depending on how the work under planning period is organized, different capacity is available. Main components are theoretical work time per shift in minutes, number of shifts, number of workdays under period and utilization rate of work time in percentage. They form together available work time in minutes. That is the capacity of a resource. Figure 5.3 shows these components in the tool.

Capacity Forging	
Theoretical worktime per shift (mir	480
Nr of shifts	1
Nr of workdays under period	22
Utilisation rate of worktime (%)	70
Available worktime (min)	739200

Capacity Heat
Theoretical worktime p
Nr of shifts
Nr of workdays under p
Utilisation rate of work
Available worktime (mi

Capacity Shot Blasting	
Theoretical worktime per shift (min)	480
Nr of shifts	1
Nr of workdays under period	22
Utilisation rate of worktime (%)	70
Available worktime (min)	739200

Capacity Thread Turning	
Theoretical worktime per shift (mir	1920
Nr of shifts	2
Nr of workdays under period	20
Utilisation rate of worktime (%)	60
Available worktime (min)	4608000

***Figure 5.3**. A partial view of the capacity sheet in the Excel based tool.*

Guidelines have to be made on which components form utilization rate, and how it is calculated. One possibility is to use the determinations of OEE –term. OEE stands for Overall Equipment Efficiency. Organization has already some familiarity with the term and the IT –system installed in the machines and provided by company Fastems has a possibility to start using OEE measurement. Similar determinations can be used on resources which are not suitable for the Fastems IT –system.

5.1.1.5 Algorithm

The algorithms which are needed to create the shop floor view of the tool are simple. They require only minimal programming skills. Basic knowledge of Visual Basic for Applications (VBA) is enough. Algorithms are in principle as follows:

$$L_{resource} = L_A \times T_A + L_B \times T_B +_{...} \quad (2)$$

$$C_{resource} = \frac{L_{resource}}{T_{available}} \quad (3)$$

In the formula 2, $L_{resource}$ is total load in min for the resource, L_A is load of a product A in wanted time period in pieces, T_A is the standard time a product A takes in a resource and with the same logic all the planned products which are to be produced are added to the formula.

In the formula 3, $C_{resource}$ is used capacity of a resource in percentage, $L_{resource}$ is total load in min for the resource and $T_{available}$ is available work time of a resource in minutes (i.e. capacity).

If we would look at capacity on shorter time period than one month, then we would have to take the prioritization logic in work queues in front of resources into consideration. This logic was mentioned earlier under headlines; 5.1.1.3 Item mix under planning period and 2.4.1 Material Resource Planning 2 in Enterprise Resource Planning. In this case we would start to come to the area of finite scheduling instead of rough cut capacity planning. Algorithm which would take the logic into consideration would be more complex but not difficult. Also the work on the shop floor would have to be organized and done according to the algorithm. Otherwise it would solve something that doesn´t really happen.

5.2 No for Kanban, maybe for Conwip

In this environment, Kanban doesn´t work. In PU Sandviken the raw material forms a significant part of the production cost, there are around 400 items and standard deviation of demand is rather big.

Rule of a thump in classical optimized Japanese style Kanban system is that Kanbans should be updated always when volume change more than 30 percent (Kouri, I. 2012). In Kanban system, each item is stocked. In order to work, Kanban needs stocks between the functions on the production process plus finished goods stock. If standard deviation is big, it means that a lot of material has to be stocked in order for Kanban to work.

To get 85 percent delivery accuracy with one month replenishment cycle, stocks have to be the size of average monthly demand $\pm$ standard deviation. Default is that the demand follows Normal Distribution curve. Is the demand following Normal Distribution curve can be checked by plotting frequencies/incidents to a chart and looking does the curve visually resemble Normal Distribution curve. When replenishment time is one month, rule of a thump is (Kouri, I. 2012):

$$85\%\ A_D : D_{month} \pm S_D = SL_A \qquad (4)$$

$$92\%\ A_D : D_{month} \pm 2 \times S_D = SL_B \qquad (5)$$

In formula 4 is shown the formula to calculate the needed stock size for 85 percent delivery accuracy. In formula 5 is calculation for the 92 percent delivery accuracy shown. Both formulas and formula 6 have similar notation; A_D is delivery accuracy, D_{month} is average monthly demand in pieces, S_D is standard deviation in pieces and SL_A is stock limit in pieces.

One indicator for suitability of P&C method is following formula:

$$R = \frac{S_D}{D_{month}} \qquad (6)$$

When R starts to close 1, it becomes difficult to control the production with pull methods and especially with Kanban. Push based methods are more likely to work.

In table 6.1 is presented the situation for T23. Monthly demand is presented and average variability of monthly demand. Data is from period March 2011 – February 2012.

Table 6.1. *Average demand per month, standard deviation and std.deviation/demand ratio under period March 2011 – February 2012.*

Item	Average	Std.dev.	Ratio	Item	Average	Std.dev.	Ratio
7854-8643-20	716	502	0,70	7324-8631-20	46	72	1,56
7324-9637-20	515	349	0,68	7324-9624-20	46	179	3,92
7853-2426-20	439	745	1,70	7853-7633-20	45	42	0,94
7324-8543-20	424	1056	2,49	7853-2433-20	40	46	1,16
7324-9643-20	418	378	0,90	7853-2429-20	38	38	1,00
7324-6543-20	387	220	0,57	7327-5437-20	36	33	0,90
7853-2427-20	371	163	0,44	7324-7249-20	35	33	0,93
7324-8537-20	360	1672	4,65	7854-8737-20	35	58	1,66
7854-8649-20	355	335	0,95	7853-2421-20	34	144	4,19
7854-9643-20	332	190	0,57	7327-5261-20	34	31	0,89
7853-2424-20	328	204	0,62	7327-5249-20	33	39	1,18
7324-9631-20	319	725	2,28	7853-7637-20	31	27	0,85
7324-8643-20	273	197	0,72	7853-8727-20	31	79	2,55
7324-4149-20	261	149	0,57	7853-7627-20	29	21	0,73
7324-4137-20	248	188	0,76	7324-9664-20	29	31	1,06
7324-9649-20	236	141	0,60	7324-4128-20	28	163	5,91
7854-9631-20	212	219	1,03	7324-7261-20	27	34	1,24
7324-9655-20	197	93	0,47	7324-4126-20	27	113	4,24
7854-8637-20	196	165	0,84	7324-6549-20	25	63	2,54
7324-4143-20	186	112	0,60	7854-8646-20	20	170	8,49
7324-4155-20	180	205	1,14	7854-8937-20	20	5	0,23
7324-6731-20	178	348	1,95	7854-8755-20	17	0	0,00
7853-7631-20	177	97	0,55	7324-9661-20	16	20	1,23
7853-7624-20	176	209	1,18	7324-4124-20	15	29	1,99
7853-2420-20	171	189	1,11	7853-24114-20	12	2	0,17
7324-6749-20	168	404	2,40	7324-8561-20	12	9	0,77
7853-2431-20	157	184	1,17	7854-8724-20	11	68	5,99
7324-4131-20	150	86	0,57	7853-2410-20	11	92	8,49
7324-6537-20	124	85	0,69	7853-2437-20	11	29	2,76
7324-8555-20	101	70	0,69	7327-0761-20	10	21	2,11
7853-7643-20	96	152	1,59	7854-86442-20	10	17	1,73
7327-5255-20	95	102	1,08	7324-6531-20	10	14	1,37
7854-9655-20	86	84	0,98	7853-3031-20	8	21	2,58
7324-7255-20	84	46	0,55	7324-9665-20	7	57	8,49
7324-8637-20	81	82	1,01	7324-8749-20	7	55	8,49
7324-9640-20	79	87	1,09	7853-7621-20	6	54	8,49
7854-8731-20	79	171	2,16	7327-61635-20	6	47	8,49
7324-6755-20	77	437	5,71	7854-8624-20	5	8	1,80
7854-9637-20	76	69	0,92	7324-4264-20	3	13	4,02
7854-8631-20	73	38	0,53	7327-5243-20	3	8	2,94
7327-5264-20	67	46	0,69	7324-4249-20	3	21	8,49
7854-9649-20	66	59	0,89	7324-4243-20	2	3	1,19
7324-6737-20	65	103	1,57	7324-4231-20	2	4	2,01
7853-8724-20	65	95	1,47	7327-0755-20	2	17	8,49
7324-7243-20	64	29	0,44	7324-6361-20	2	16	8,49
7324-8549-20	64	120	1,89	7324-7043-20	0	1	8,49
7853-7626-20	62	38	0,61				
7324-6743-20	58	242	4,17				
7324-6555-20	55	67	1,22				

Conwip instead might work but needs restructuring of the real manufacturing process. Conwip is pull based method but whereas Kanban guides individually separately every item, Conwip guides the manufacturing route. Often one material flow is one route.

When a product is finished with operations on defined stage on the route, Conwip card is sent over number of operation stages to the beginning of the route. The card gives a permission to start the next product on the work list.

This is a pull method but it does not require keeping WIP –stocks for every item between the manufacturing operation stages. It works better when there are many items being produced in a route/material flow. For example material flow T23 has 95 items. Using Kanban would mean having 95 WIP –stocks between every manufacturing operation stage.

Manufacturing process on the shop floor would have to be restructured in order for Conwip to work. Conwip needs independent material flows. Independent material flows would have to be formed. This means that shared resources would tried to be avoided. Shared resources would be made unshared for example by dedicating a specific capacity to each material flow.

In rod production one possibility would be to organize independent material flows on operations before heat treatment. Heat treatment would be a shared resource. There would be a stock in front of heat treatment. Heat treatment would operate with First-In-First-Out, FIFO –principle. Second set of individual material flows would be formed between heat treatment and surface treatment. Surface treatment could be a second shared resource. There would be a stock in front of surface treatment and it would operate with FIFO –principle.

For material to flow smoothly and for planning to be simpler, it would be needed that the surface treatment has more capacity than heat treatment. Same applies for the other operations. Investments and work organization would have to be done in a way that heat treatment is always the bottleneck.

In case of PU Sandviken rods production, it doesn’t matter is the shop floor P&C done by push or pull (Kanban or Conwip) method. Rough cut capacity planning (RCCP) can be done the same way (Andersson 2012).

5.3 Heijunka – Production Leveling

Heijunka is a Japanese term and stands roughly for production leveling. Like mentioned earlier, variability means costs. Heijunka aims to form smooth steady flows with minimal fluctuation. Variability on the supply chain was shown in 4.2. Variability in production and supply chain.

Currently production planning doesn´t have a good view of the stockroom 12 warehouse values. ROPs in the stockroom release production requests to the PU Sandviken. Visualisation of stockroom 12 live -situation would increase possibility to see how demand fluctuations develop and how the overall situation looks like. If you add to it a production planner´s understanding on what information about market demand ROP algorithm carries inside, better decisions on production plan could be formed. For example sometimes it might be good and cost efficient to produce some products before they hit ROP. With increased visibility can be flow balancing done better and variability decreased.

In the figure 7.1 is effect of stockroom12 visualisation and Heijunka illustrated. Functions are from left to right; Real customer orders, regional warehouse ROP, stockroom 12 ROP, PU production planning and production process, supplier and supplier´s supplier.

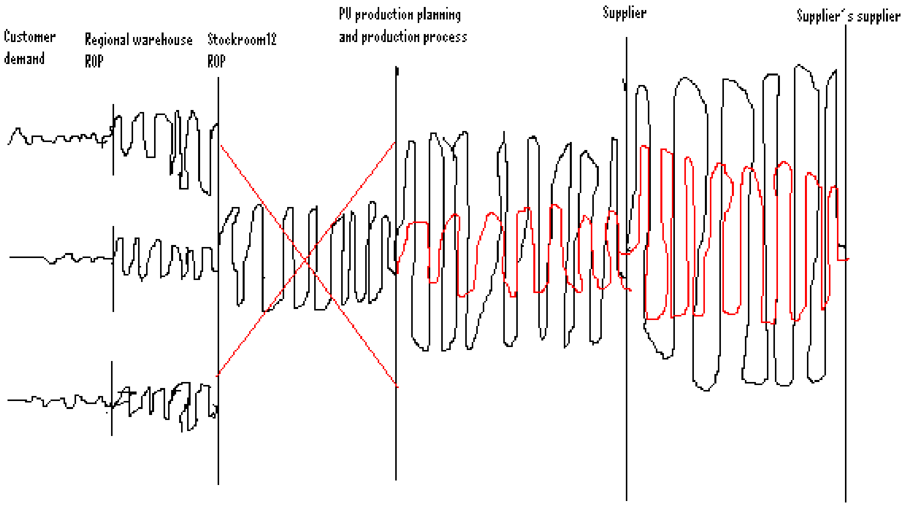

Figure 7.1. *Effect of stockroom12 visualization and production leveling on supply chain.*

Visualization is easy to do on Excel. Visualisation on Excel is not visually as attractive as commercial software solutions but will give 90 percent of the benefits, is fast and cheap to build, easy to modify and improve and knowledge to build it exists already in the Rock Tools organization. Sandvik Supply Chain IT -system Specialist John Salyer can be contacted on questions concerning technical issues.

6 RESULT

Many issues were brought up in the earlier chapters and even more were left unnoticed. This was due to a nature of the study as a Master Thesis. Everything is connected to everything. Some of the key points are summarized and proposition, which would bring most benefits versus cost and needed time, is highlighted in this chapter. The proposition tackles the main problem in rods production in PU Sandviken.

6.1 Excel based rough cut capacity planning tool

The production unit has difficulties to keep what it promises. This means there are problems in making and executing the production plan. The production unit cannot reliable say what volumes and which item mixes it can make. There is a reason for that. Production environment has moving bottlenecks but still production planning is done by expecting the bottleneck to stay mostly at the same place. Production environment has multiple shared resources and the material flows interact with each other. Still production planning is done more by looking at individual material flows instead of the whole. The main issue would be to get the big picture right. Then the production unit could communicate more reliable information on its production capabilities to other players in the supply chain. This information is needed specially when having product area Rock Tools S&OP meeting. Additionally, there would be a lot of PU internal benefits.

To get the big picture right, the rough cut capacity planning has to make the moving bottlenecks visible. If the bottlenecks and loads on resources are not visible, it is difficult to know the doable through-put volume and item mix combination.

Currently production planning and shop floor work organization relays a lot on historical experience. With historical experience, meaning fingertip feeling, can a production planner utilize only a part of the capacity. For example maybe the production planner can utilize 70 percent of the possible capacity. It is ok, but the money is been made on that missing 30 percent. When a demand changes a lot, new machines are bought or situation changes somehow, the production has to get the needed historical experience by trial-and-error. This is expensive. Macro-economic cycle times in the world are getting shorter and gravity of the changes bigger. Meaning, that also macro trend is not supporting this type of production planning.

Main PU internal benefits from the rough cut capacity planning tool are:

- On the shop floor: right men, at the right time, at the right place. This leads to cost efficient smooth material flow and maximum through put volume.

- Better delivery accuracy because capacity requirements information is more accurate. Doable production plan is made and work on the shop floor is organized accordingly.
- When capacity needs can be estimated better, less stock and time buffers are needed
- In planning stage can already an effect of maintenance works, training days and other events seen and production plan made in a way that material still flows smoothly
- Three years simulation tells what type of personnel and machine investments is needed in order for material to flow smoothly on the shop floor also in future. On the issues can be reacted before they turn into problems.
- Especially during economic downturn more accurate information on capacity requirements is needed. It is important to know where the bottlenecks are probably going to be in three months - half a year interval. It can be also decided where bottlenecks are, by organizing work on the shop floor accordingly. By having just the right amount of capacity at the right places can profit be made also during these times by maintaining good cost – customer satisfaction ratio. Excess capacity and costs have to be cut down. That means also lay-offs and other harder resource balancing measures. When making these hard decisions, accurate information on near future capacity requirements is valuable.

Many software vendors offer rough cut capacity planning tools. Excel might not be as sophisticated as commercial software solutions but will give 90 percent of the benefits, is fast and cheap to build, easy to modify and improve. Also the knowledge stays inside the house. During the time smaller and bigger changes happen in the production environment. The tool has to be updated once in a while that it gives good answers. If vendor is used, changes are costly and take time to make. Commercial software often offers better automation and nicer looking interface but the downside is that it cast everything into concrete. Changes are hard to make. That’s why in every case, it is recommended that a process is first studied and learned deeply with Excel type light solution. Then, if wanted, can a commercial solution be applied to it. One has to know what he is buying.

6.2 Decreasing number of planning variables

Production environment has a lot of planning variables which all should be noted when making production plan. It is difficult. Even with the rough cut capacity planning tool, it would be good to decrease the planning variables. It would make easier for production planner to understand the dynamics on the shop floor.

Tool does the math, which is too difficult for a human to do in the head, but a production planner is good to understand what the tool is doing. A tool is stupid. A person needs to understand the production environment and all the variables in it. That way a person can make a tool to give an answer that fits to the reality. The tool can be continuously improved to give better answers when knowledge of the environment increases. Not a single tool in world can replace the need for a production planner to understand the production environment and the process.

Some of the possibilities to decrease number of planning variables:

- Physically simplify material flows. Put machines or functions together in a way that they resemble line. Helps in finite scheduling and shop floor control, not that much in rough cut capacity planning. In PU Sandviken possibilities for this are few because of limited shop floor space.
- Group all the similar machines together as functions and make all the machines inside that function fully compatible with each other. This also increases flexibility.
- In shared resource: Dedicate specific capacity or a machine to a specific material flow.
- Standardize activities on the shop floor: Standard times are more accurate. Most of the components that form utilization rate / OEE stay the same and are not depended on item mix.
- Stop offering the products which are sold only few times in a year. If this is not possible, move them to a supplier, move them to a factory in low cost country, move them to a competitor or build special work shop. In the work shop is old machinery used and a product is made from start to finish. Lead times can be longer. These products are service for a customer and don´t bring any profits, only costs, because they increase variability in material flows and disturb.

6.3 Visualization of stockroom 12 live situation

Benefits of visualization of stockroom 12 live situation are presented on Chapter 5.3 Heijunka – Production Leveling. This would give production planning more possibilities in planning. It would bring cost savings inside the PU and in the whole supply chain because variability decreases.

Visualisation can be quickly and cost effectively implemented in Excel. Sandvik IT –System and Process Spesialist John Salayer needs only mock-up of the wanted view and determinations on functionality. Depending on his work load, he is able to build the visualization in couple of weeks.

Few people in planning and purchasing department have previously worked in Ericsson. There is a similar way of looking at finished goods stock levels and working with it. It would probably be easy to get the support in the department for this.

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7 APPENDIX: DAILY TARGETS

This part is extra and is not in the scope of new objectives which was agreed at the end of March at 2012 in Sandviken. In this part are the original concept and ideas for the first objectives presented. They are presented very shortly without looking at them deeply. Mechanisms working behind and reasoning why things should be organized like presented are not showed.

Original plan was to study and evaluate suitability of so called Daily Targets – concept, but like mentioned earlier the organization didn't have the resources needed.

Daily Targets is also built around rough cut capacity planning tool. It is similar than one presented in the Master Thesis, but the algorithm is more complex and ways of working on the shop floor would need changes. In this case tool would build finite scheduling for each team on the shop floor. Based on that would be rough cut capacity plan created. Meaning that, capacity planning would be done from bottom to up. It would also increase accuracy of capacity planning further. In the rough cut planning tool presented in this Master Thesis, there is no finite scheduling included and rough cut capacity planning is done only on the top level.

The objective of Daily Targets is to create a daily production plan for each team on the shop floor. Functions and workers on the shop floor would be organized as teams.

7.1 Daily targets per team

Excel based capacity planning tool would give daily production plan for each team on the shop floor. Functions and workers on the shop floor would be organized as teams. All the activities and control on the shop floor would be based on team boards on the shop floor. Below is presented an example of a team board (Fig. 7.1).

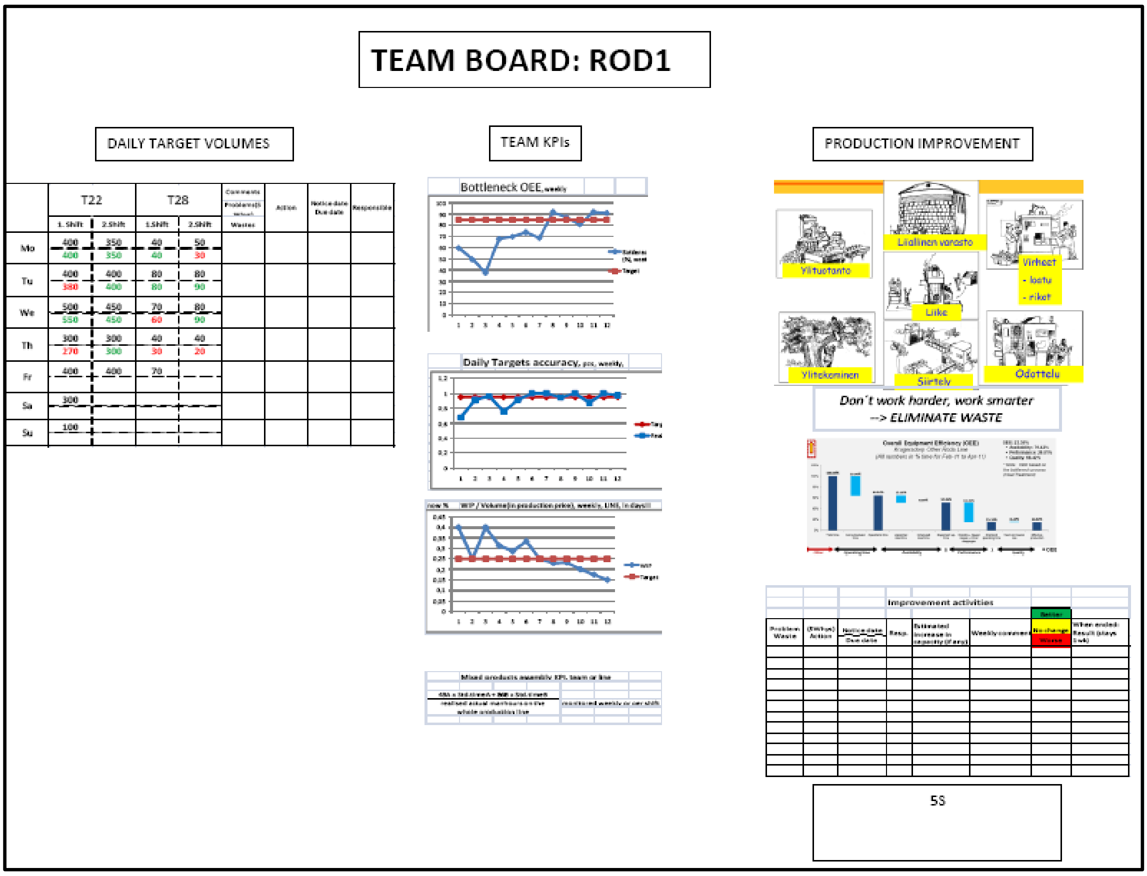

Figure 7.1. *An example team board*

There are three areas on the team board. These are production plan, KPIs and production improvement.

7.1.1 Daily production plan for a team

Most important is the table on left under the headline; daily target volumes. That is daily production plan for a team. All the activities on the shop floor are built on top of it. Below (Fig. 7.2) is the table presented closer.

DAILY TARGET VOLUMES

	T22		T28		Comments Problems(5 Whys) Wastes	Action	Notice date Due date	Responsible
	1. Shift	2.Shift	1.Shift	2.Shift				
Mo	400 400	350 350	40 40	50 30				
Tu	400 380	400 400	80 80	80 90				
We	500 550	450 450	70 60	80 90				
Th	300 270	300 300	40 30	40 20				
Fr	400	400	70					
Sa	300							
Su	100							

Figure 7.2. *Daily production plan for a team.*

In the figure 7.2 is shown a daily production plan for a team. Team is a shared resource for two material flows. These are T22 and T28.

In the figure today is Friday. The numbers in black are the production plan. Red color is used when result was less than production plan and green when team was able to follow the production plan. Numbers are pieces or batches produced.

In this example production has one week freezed production schedule. New production schedule for the next week is created every Friday afternoon.

To make production system and algorithm simpler, good pace for material to flow from stage to stage in production would be one day or one shift. The flow would be easier to everybody to understand and control. Shop floor workers would start to control partly independently the flow and production plan accuracy.

Everybody wants to be good. Men more the women build a big part of their self-esteem from the work. When the weekly production plan is visible, shop floor workers know what is expected from them. When they accomplish daily production plan, they know they have been good and can go home feeling proud of themselves. When a team does couple of weeks in a row a delivery accuracy of 100 percent (i.e. daily adherence to the production plan), they start to become proud of it. When it happens, that one day it seems like they are not going to make it, the team is willing to do a lot to hit that 100 percent.

Significant benefit of the method is that deviations on the production plan can be reacted right away when delivery accuracy is tracked for every team (production stage). It is good to keep in mind following. When team does 95% delivery accuracy it seems good, but the end result is something different. For example material flow T23 has nine stages. In an example scenario every team does 95% delivery accuracy. In this case it would mean 95% x 95% x 95% x 95% x 95% x 95% x 95% x 95% x 95% = 63%. As an end result, delivery accuracy of the material flow is 63%.

Four columns on the right side are part of continues improvement. When a team member notices improvement possibility, on it is right away reacted and date when it is noticed is written on the team board. Management, production development and the team works out together an action and doable due date for the action is written on the board. Now the pressure starts to come from shop floor towards management. Old way is that the pressure to improve comes only from the management. New way also improves communication between hierarchies and functions.

In order for continues improvement to work, it needs time from the daily work and also from the management. It is important that the shop floor workers see that on their every notice and idea is reacted.

If organization doesn’t have the time, then it is better that it is not implemented. Another lighter way to do improvements is then better and more suitable. Analogy would be that if you can use only two wheels, build a bicycle instead of car. Bicycle will give you much more benefits than a car that drags itself with two wheels 2km/hour. This type of car creates mainly frustration.

7.2 Team KPIs

Team KPIs tell to a team how well historically they have been doing and are they developing. These are the main indicators for how well the factory is working. Good numbers in these will result in high productivity and profit on the factory level.

It is good also to notice that team members can affect these numbers. They cannot affect for example Sandvik Group ROI figures. That’s why Sandvik ROI figures are no interest to them. That’s why factory numbers should be kept on a factory board. A production manager can once a week take a team to a factory board and tell them how the production system as whole is doing and how a team´s work last week affected factory KPIs. He can also ask what the team could need from management and other teams to improve their team KPIs.

7.2.1 Delivery accuracy

Main KPI is for a team is delivery accuracy (Fig. 7.3). It tells how reliable a team or factory operations are. Better the production planning and control is, more stable is the production process and fewer disturbances occur. Disturbances mean costs. When a production unit is reliable, it makes planning for the other functions outside production unit easier. When other functions can plan better, they save costs.

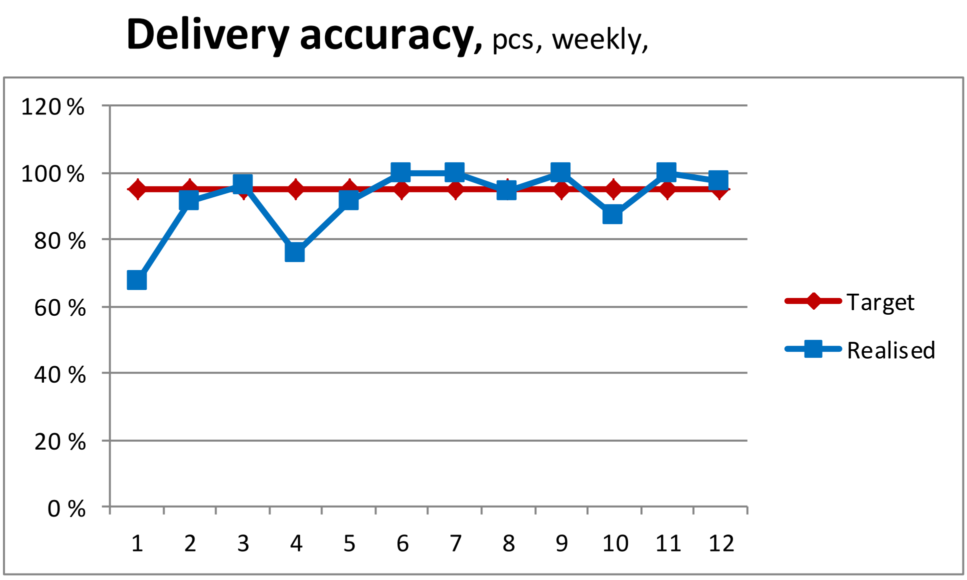

Figure 7.3. *Delivery accuracy of a team. Team KPIs.*

Daily delivery accuracy of a team is been tracked (Fig. 7.3). It gives a possibility to see are the ways of working improving.

7.2.2 Team OEE

Whereas delivery accuracy tells to a team; are we able to follow the production plan, OEE –chart tells how the productivity inside a team is developing (Fig. 7.4).

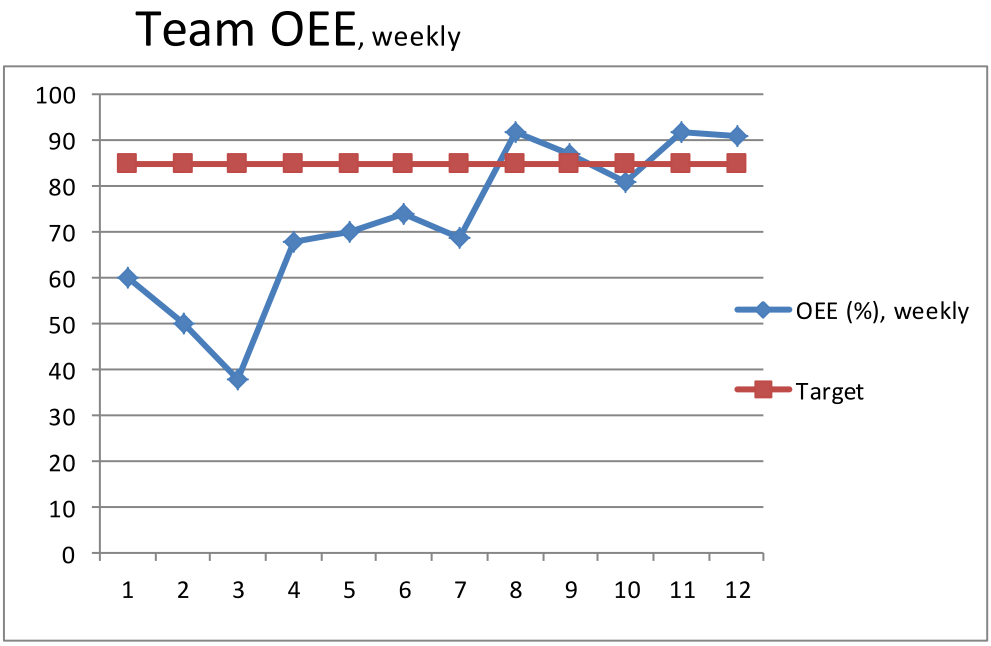

Figure 7.4. *Team OEE –chart. Team KPIs.*

Guidelines on how the OEE is calculated have to be formed first like mentioned in the chapter 5.1.1.4. Available capacity. It is good to notice that OEE is measured against planned production time. Planned production time for a team will come from the Excel based capacity planning tool. OEE is best suitable for teams in which most of the costs come from machines, not from machine operators.

To get a good efficient material flow and to make a profit, all the machines should not be tried to be run 24/7. Work is organized according to the moving bottle-necks.

7.2.3 WIP compared to volume

To get best possible ROI; one of the targets is to run operations with as little capital as possible. In raw material, WIP and finished goods (including goods in transit) stocks is capital tied to them.

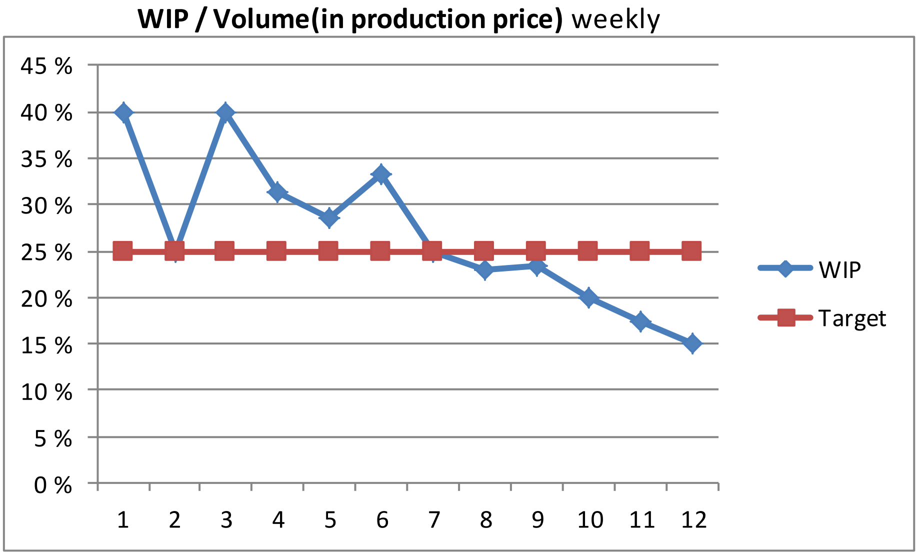

Figure 7.5. *WIP stocks compared to the production volume. Team KPIs.*

This KPI is for the material flow or for the whole production system. The choice depends on how advanced the internal accounting in the factory is and what are the ways of working.

The KPI is not WIP and production volume inside a team. This KPI is exception. It is the same KPI as on the factory board. The reasons for this are following.

- Accounting wise it would be heavy to do this type of tracking for each team. Workload/benefit ratio would be bad.
- It helps shop floor personnel to see that what my team does affects other teams. The KPI helps personnel to see the manufacturing as a one functioning system with interactions. It reinforcements process type of thinking on the shop floor.

The less WIP there is in the manufacturing, the leaner production is. It is easier to see the problems in the manufacturing process and fix them. Problems are not hidden under WIP –stocks.

7.2.4 Assembly team productivity KPI

When a team is doing mainly assembly work a KPI can be used by utilizing following formula. For an assembly team the KPI tracks productivity development.

Mixed products assembly KPI

$$\frac{49A \text{ x Std.timeA} + 86B \text{ x Std.timeB}}{\text{realised actual manhours}}$$

Figure 7.6. *Assembly team KPI formula for productivity development. Team KPIs.*

In the example formula, 49 units of product A and 86 units of product B was produced during the time period.

7.3 Production improvement

Constant improvement and exercise of Lean ideology are these days often a wish from management towards production and the company´s other functions. These are good methods but it should be avoided that they don´t become a value on their own; a value that overrules everything else. Implementing a concept one to one, 1 : 1, probably will not bring as good results as implementing it 1 : 0.7. Adaptation and adjustment is needed especially when a company is creating unified global processes. Production environments differ. Here a PU manager plays an important role. Production improvement is supporting function. Production improvement and new trendy fashionable methods and concepts should not become a higher value than actual manufacturing. A method or concept should not be implemented only because it is currently fashionable. A following is a proper hierarchy chain:

1. Adherence to the production plan.
2. KPIs.
3. Production improvement.

Production improvement helps to improve KPIs and KPIs help to improve production plan adherence.

7.3.1 Seven wastes

Lean method has summarized well seven points of ineffective working (Fig. 7.7). These are issues that shop floor workers and middle management can impact. Seven wastes are showed at the team board to teach shop floor workers to look at their surroundings and way of working. When the issue is seen daily and discussed, it slowly starts to change how the workers see their work environment. It activates improvement work on the shop floor. Pictures are used to improve cognitive process.

Note at the end is to decrease change resistance. Often people feel that the management is trying only to push to work more and longer. Idea is to make shop floor personnel believe that the objective is not for example to cut down coffee break to half.

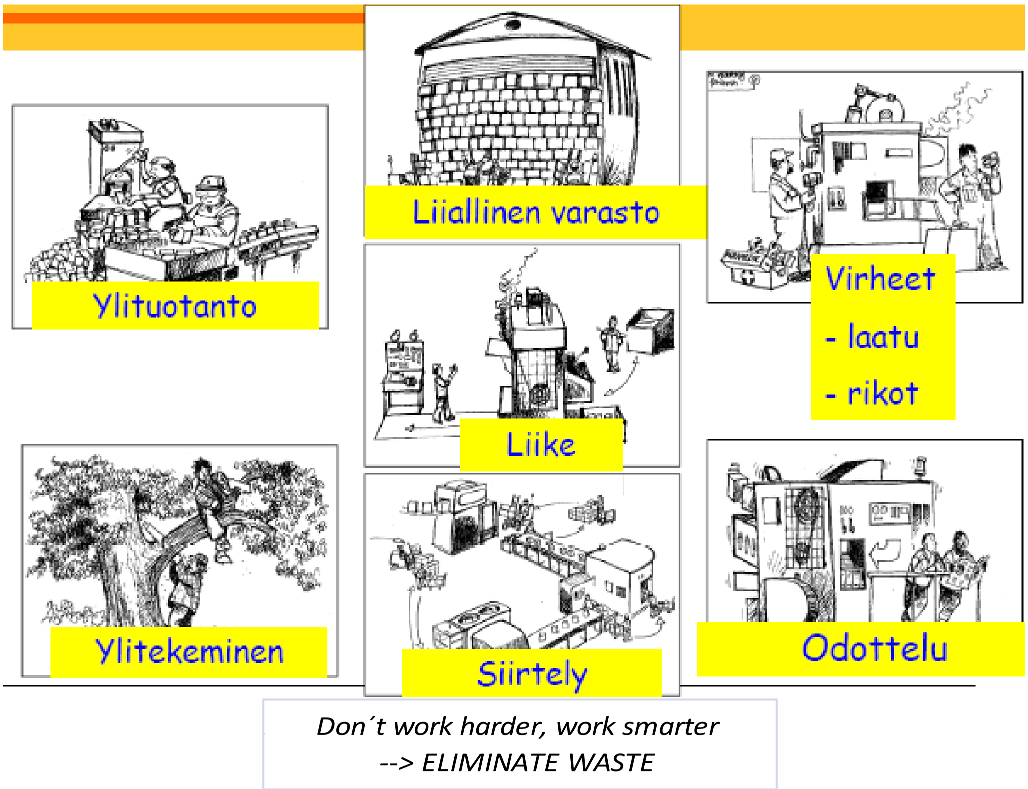

Figure 7.7. *Seven wastes in the production. Team board´s production improvement.*

Seven wastes in the figure 7.7 are written in Finnish. Local language of a PU is used. Seven wastes in English are over production, oversized stock, defects; quality and machine breakdowns, waiting, moving, movement at the work point and over doing.

7.3.2 Overall Equipment Effectiveness Analysis

Once a week or once a month is OEE analysis made and put on the team board (Fig. 7.8). It helps the team to improve their OEE KPI and activates improvement activities. This leads to improvement in productivity.

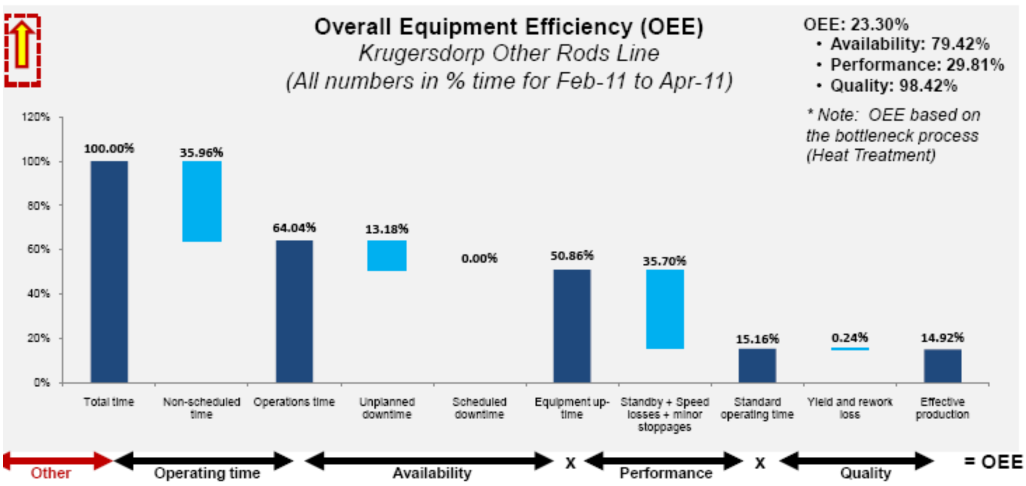

Figure 7.8. *Weekly or monthly OEE –analysis. Team board´s production improvement.*

7.3.3 List of on-going activities

Problems and improvement possibilities which are noted by the team during the week are marked on the team board as descripted in the chapter 7.1.1. If they are not handled during the week, they are moved to the list of on-going improvement activities (Fig. 7.9) Also other improvement activities in the factory which have an effect on the team, are marked on the list. It improves communication, structures improvement activities and shop floor workers see that their ideas are reacted and they are valuable. The list also starts to generate pressure from the shop floor towards white-collar workers. A person´s reputation becomes involved. The improvement system starts to run on its own without top management constantly pressurizing it. Important to remember is that improvement work takes time from a person´s daily work.

Improvement activities

Problem Waste	(5Whys) Action	Notice date / Due date	Resp.	Estimated increase in capacity (if any)	Weekly comment	Better / No change / Worse	When ended: Result (stays 1wk)

***Figure 7.9** List of on-going improvement activities.*

The list (Fig. 7.9) has eight information fields:

- In Problem/Waste is noticed problem, waste or improvement opportunity marked
- In 5 Whys, Action is the action marked which was result of thinking with the team and other suitable personnel possible solution. 5 Whys is a technique which helps to find the root cause. The technique is to be taught to the personnel.
- In Notice date / Due date is day of notice and agreed due date marked.
- In Resp. is the name of a person responsible for the solution marked.
- In Estimated increase in capacity is marked what benefits successful solution will bring. Preferable clear benefits like improved capacity in pieces or saved cost in money are used.

- In Weekly comment is a comment written by the person responsible for the action how the action is progressing.
- In Better/No change/Worse is marked how well the planned timetable for the action is holding.
- In When ended: Result, is marked what was the final outcome. Also if an action is cancelled, it is marked here and reason written. After the action is finished and result is written, it stays on the list one week or more. It gives people a feeling of accomplished and that everybody can make changes in their working environment.

7.3.4 5S methodology

5S (Sorting, Straightening, Shining, Standardizing, Sustaining the Practice) methodology is a Lean tool. Often it is viewed mainly as a cleaning operation. The main point is not that it helps to keep places clean and nice looking. Main point is that the 5S is a tool supporting Lean thinking. It helps personnel to see the seven wastes in their working environment. 5S on its own without seven wastes connection does not bring much extra productivity.

When implementing 5S, it is recommendable that the connection between the seven wastes and 5S is taught to the personnel.

Like mentioned 5S is a production improvement tool and is the last function under production improvement on the example team board (Fig. 7.1). White blank chart is showed on the example team board. Wanted layout on a PU´s local language is to be used.

7.4 Activity based costing

ABC (Activity Based Costing) accounting can be implemented when work on the shop floor is organized to teams and activities like suggested in the chapter 7. ABC accounting helps to improve team boards, control the production process and develop operations further by providing the organization with more accurate data. Benefits of the ABC are few if the manufacturing process is not first organized suitable for this type of accounting.

7.5 Summary

The concept presented in chapter seven is one system. The functions on the team board are linked and support each other. This concept was discussed more from the view point of shop floor personnel. The shop floor personnel do the actual work in the manufacturing process. The concept showed a P&C method for the process and included production improvement. Implementation of the concept had two main requirements; development of production planning tool and changes in the manufacturing process. Nature of the chapter was more conceptualizing and opening floor for the discussion.